JOURNAL OF THE AMERICAN WELDING SOCIETY

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Our New President

Our new President, Frank P. McKibben, is a bridge engineer of international reputation. He has acted as designing engineer and engineer of construction on a drawbridge of the City of New Bedford; as designing engineer of the elevated railway structure and buildings of the Boston Elevated Railway Company. At one time he was connected with the Berlin Iron Bridge Company and the Edge Moor Bridge Company, which was later absorbed by the American Bridge Company. As Assistant Bridge Engineer for the Massachusetts Railroad Commission he made calculations for and examined 1500 railroad bridges and 800 highway bridges during a period of six years. President McKibben for ten years had in charge the operation of the Fritz Testing Laboratory which he designed and equipped. He acted as consulting engineer to the Attorney-General's Office of Pennsylvania in the investigation of the Austin, Pa., dam. He was also consulting engineer for the Pennsylvania Water Supply Commission in 1914.

He designed the following structures: Connecticut River Bridge at Chicopee, Mass.; Merrimac River Bridge at Haverhill, Mass.; Bridge at Gloucester, Mass.; Bridge at Beverly, Mass.; Twenty-three Bridges in Western Massachusetts; Bridge in Central Park, Schenectady, N. Y.; New Bedford, Mass., drawbridge with revolving weight of 2,000,000 lb.; steel work for New Bedford Saving Bank.

He was engineer in charge of design and construction of Venango County Bridge, Oil City, Pa.; Smith Street Bridge, Rochester, N. Y., Ridge Road Bridge (Veterans' Memorial), Rochester, N. Y.

Welding.

In 1922, with Ernest Humphrys, made the first tests on fillet welds in longitudinal shear.

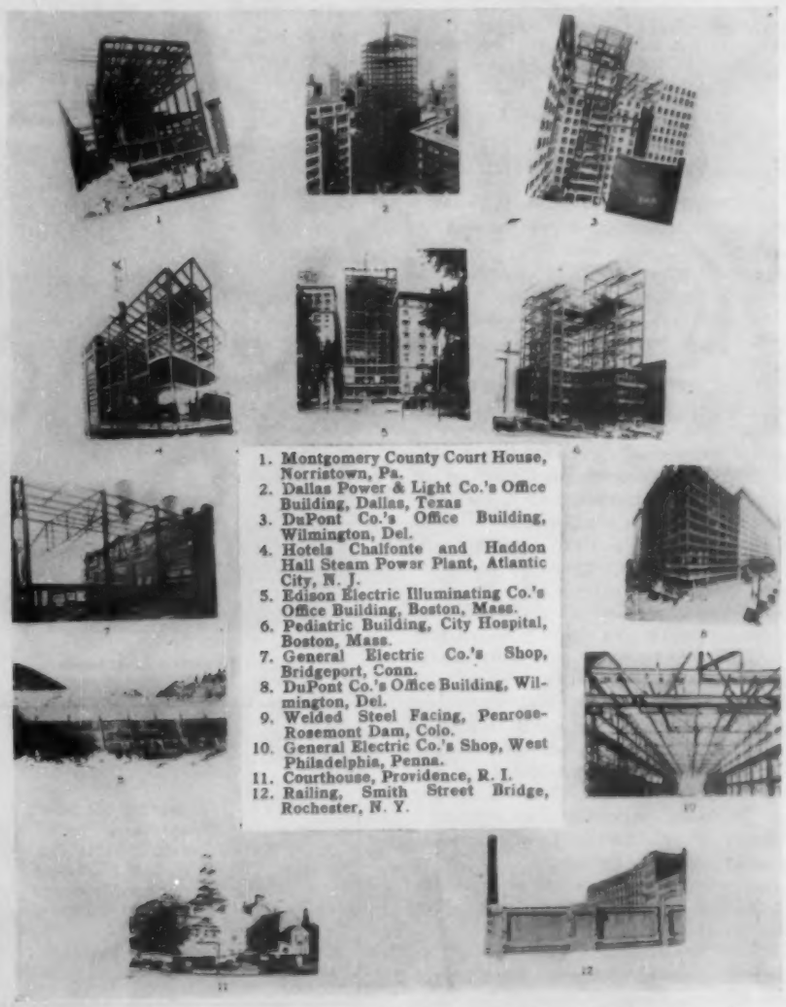
During the period 1927 to date, has been connected with welding the following structures:

1. Montgomery County Court House, Norristown, Pa.
2. Dallas Power and Light Company's Office Building, Dallas, Texas.
3. DuPont Company's Office Building, Wilmington, Del.
4. Hotels Chalfonte and Haddon Hall Steam Power Plant, Atlantic City.
5. Edison Electric Illuminating Company's Office Bldg., Boston, Mass.
6. Pediatric Building, City Hospital, Boston, Mass.
7. General Electric Company's Shop, Bridgeport, Conn.
8. DuPont Company's Office Building Addition, Wilmington, Del.
9. General Electric Company's Shop, West Philadelphia, Pa.
10. Court House, Providence, R. I.
11. Welded Steel Facing, Penrose-Rosemont Dam, Colorado.
12. Railings, Smith Street Bridge, Rochester, N. Y.

During the period 1927 to date has addressed over 101 audiences (total attendance 15,500) on the subject of structural steel welding, and has written 71 articles pertaining to welding.

He has also acted as City Engineer for the City of Schenectady for two years and had charge of the design and construction

Frank P. McKibben



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Some of the Welded Structures with Which Our New President Has Been Connected

of sewers, streets, boulevards, costing several million dollars. He has acted as consulting engineer for more than thirty different companies.

Publications.

"Steel Bridge Construction" in American Civil Engineers Handbook; "Concrete Arch Bridges" in Concrete—Plain and Reinforced; about 160 technical articles (other than those pertaining to welding) in scientific and technical journals and in publications of engineering societies; seventy-one articles relating to welding.

Teaching.

Professor McKibben has had more than twenty-two years teaching experience at M. I. T., Lehigh University and Union College.

Welding Society Affiliations.

Professor McKibben is also well known to the Welding Society, having served as Senior Vice President for two years, member of the Board of Directors and Executive Committee, Structural Steel Welding Committee, Structural Steel Welding Steering Committee, Committee on Building Codes and Committee on Pipe Welding. He has been awarded the 1931 Samuel Wylie Miller Medal for his outstanding work in the development of the art of Structural Fusion Welding.

Under his administration the Society can look forward to continued growth, and usefulness.

Annual Meeting

The most successful annual meeting of the Society from every viewpoint was held on April 27th, 28th and 29th. The outstanding features of the meeting were the technical sessions and, particularly, the Symposium on Ductility in Welds. Altogether there were 23 technical papers presented. One session was devoted to shipbuilding. There were a large number of papers featuring the results of research work. The welding of special alloys received considerable consideration. Most of the papers were preprinted in advance in the April issue and sent out to the entire membership. Preprints of additional papers were available at the meeting.

The registered attendance numbered 260 with representation from all parts of the country. One technical paper was presented in person by a visitor from Belgium.

Another successful feature of the annual meeting was the Annual Dinner on Thursday at which nearly two hundred members and guests enjoyed a good dinner and a scientific program with demonstrations on electronics. These scientific features were supplemented by a carefully planned musical program. Special thanks are due to Messrs. P. W. Swain, J. W. Gray, C. Kandel and W. Spraragen, for the arrangements as to dinner and program, and to the following companies who furnished the entertainment without charge to the Society: Westinghouse Elec. & Mfg. Co., General Electric Company, Weston Electrical Inst. Corp., Compres Oscillator Corp.

The Structural Steel Welding Committee at its meeting on Friday afternoon, April 29th, presented a program of its proposed future investigations which was endorsed by the committee. The annual meeting of the American Bureau of Welding immediately followed. The principal features were the annual report of the Structural Steel Welding Committee, the review of the committee's activities and a thorough discussion of the activities of the Fundamental Research Committee. Thirty-three investigations now under way were listed by the Chairman.

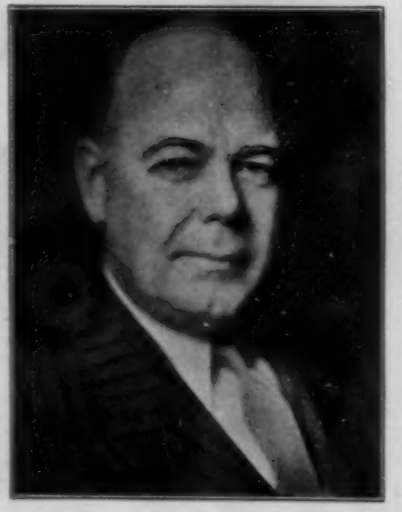
The usual business session of the Society marked the opening of the meeting. The retiring president presented the high spots of the numerous activities of the Society. Mr. Doyle's complete report is published in this issue. The meeting of the Board of Directors was held on Wednesday evening at which were appointed the usual standing committees and officers.

AMERICAN WELDING SOCIETY

Report of the President for the year ending March 31, 1932. (This report in abstract presented at the Annual Meeting of the Society, April 27, 1932.)

This report of your President for the year ending March 31, 1932, is a review of the Society activities for the period covered, and touches only in a brief manner on the further activities of the various committees herein mentioned. Each committee chairman has submitted an Annual Report, from which only portions have been taken because the complete reports themselves will eventually appear in print and also for the reason that the originals are on a file in the Headquarters of the Society and are available for perusal of those members who may find it of interest to read them.

An endeavor will be made to have this report handle the various committee matters in the sequence to which you are accustomed, by virtue of past reports having followed a more or less set method.



Past President E. A. Doyle

Membership

The past year has been a trying one from the point of view of membership for all scientific and technical societies, and the AMERICAN WELDING SOCIETY is no exception to this rule.

For the first time in the history of the Society, the curve of the growth of the Society which has been steadily upward in the past, has turned downward. However, the Membership Committee believes that this is a temporary condition and with the return of business to normalcy that the curve will again turn upward.

The total number of members, as indicated by the tables attached, is 1374, compared with 1424 at the same time last year. It is interesting to note, however, that 170 new members were secured during the year which was offset by 220 resignations and those dropped for delinquency.

The Committee has not been very active during the past year largely due to a lack of funds at its disposal. A leaflet setting forth the activities of the Society and the advantages of membership was prepared and published, and has proved effective in the securing of new members.

Several attempts at circularization of selected lists of prospective members were made during the year, and although it is believed that this missionary work will be productive of results in the future, nevertheless it was found that the immediate returns just about balanced the cost of the circularization work.

Finance

The total receipts during the Society year ending March 31, 1932, were $36,548.86. The corresponding disbursements were $33,499.78, which, as compared to Society year ending 1931, shows a decrease in receipts of $8,909.83, and a decrease in disbursements of $10,308.93. The

Class		Membership 1930	1931	1932
(A)	Sustaining Members	44	40	33
(B)	Members	498	443	403
(C)	Associate Members	476	615	639
(D)	Operating Members	279	273	257
(E)	Honorary Members	3	3	2
(F)	Student Members	43	50	40
	Total.....	1343	1424	1374

(*Continued on page 33*)

The Effect of Ductility on Security in Welded Connections—Methods of Its Measurement

By D. Rosenthal

†Paper was presented before the Annual Meeting of the American Welding Society in New York, N. Y., at the Symposium on Ductility, April 28th, by D. Rosenthal. Chef de travaux, Brussels University, Belgium.

Introduction

THE opinion is sometimes advanced[1] that welds do not have to be as ductile as the parent metal. A riveted joint is the weakest point in a structure and therefore the most liable to stretch, but it is easy to make a welded joint as strong, and even stronger, than the assembled members. If this is the case, any great deformation occurring in welded structures will be restricted to the parent metal. According to this view, all that is necessary for safety is that the parent metal, and this alone, should possess the required ductility.

While this seems to be undeniable if only great plastic deformations are taken into account, it must be said that, in regard to the real conditions, ductility in welded connections has to provide for something more important; it has to prevent overstressing. On account of this overstressing, it will be shown that both the deposited and parent metals have to possess the factor of ductility.

Effect of Ductility on Overstressing

It may be recalled that overstressing occurs in structures as a result of discontinuities in shape or on account of holes and impurities contained in the interior of the metal. If this metal is ductile, overstressing will be arrested at the yield point, and no increase in stresses will occur until the same condition is reached in all points of the same section.

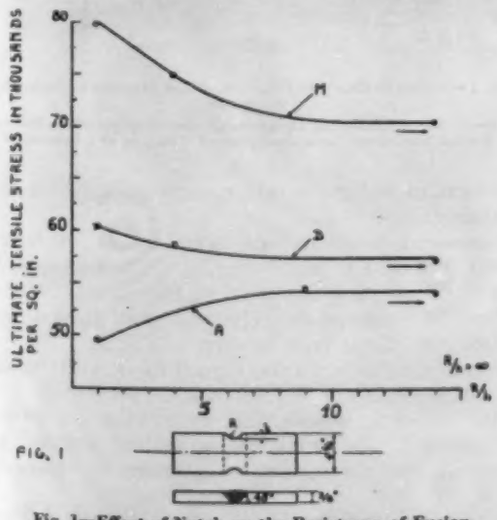


Fig. 1—Effect of Notch on the Resistance of Fusion Welded Specimens:
M—Heavy Coated Electrode
D—Light Coated Electrode
A—Bare-Wire

[1] Cf. *Journal Elektroschweissung*, Braunschweig, Germany, April 1931, p. 66.

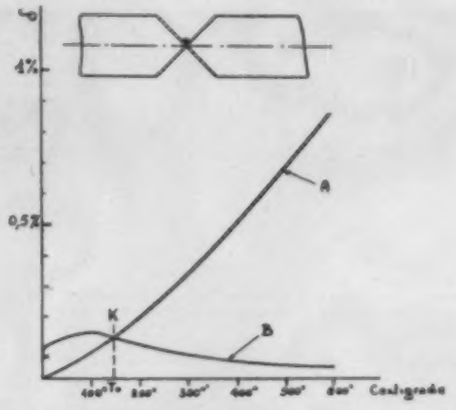


Fig. 2—Variation of Thermal Contraction and Elastic Strain with Temperature:
A—Thermal Contraction Curve
B—Elastic Strain Curve

Since ductility provides for a more uniform distribution of stresses, a greater strength may be expected in overstressed sections than as given by calculation. Experiments have indicated that this resistance may even be greater than the ultimate tensile strength of the material. This is well established for structural steel. It might be of interest to point out that this is also the case with weld deposits, provided they are sufficiently ductile.

Notched tensile specimens, as seen in Fig. 1, have been machined from plates fusion welded by means of the electric arc. Two kinds of electrodes have been used. In the first case a light coated electrode, referred to as *D*, deposits a metal of less ductility; in the second case a heavy covered electrode, referred to as *M*, makes a deposit of high ductile quality. It may be seen from Fig. 1 that the ultimate stress in lbs. per sq. in. increases in both cases, as the notch effect becomes greater, i.e., as the ratio R over h (R = radius of curvature, h = depth of the notch) decreases. The increase of resistance is, however, less marked in the case of the light coated electrode *D* than in the case of the heavy coated electrode *M*. The lower curve *A* refers to similar tests made by J. W. Owens[2] with a bare-wire electrode. No increase in strength is indicated by the diagram. On the contrary, as the ratio R over h decreases, the ultimate stress of the bare-wire deposit becomes lower. From this it may be inferred that such a deposit does not possess sufficient ductility to prevent overstressing.

Overstressing in Practice

Is overstressing occurring in welded connections as severe as that indicated in the above experiments? There are two ways in which a welded joint can be overstressed:

(*a*) during the shrinkage following fusion, and
(*b*) under applied load in service.

(*a*) *Overstressing during the shrinkage.*—In regard to the shrinkage effect let us examine, for the sake of simplicity, a thin layer of molten metal deposited by fusion between two heavy plates beveled in an X-shape (Fig. 2). Should the deposit be free to contract, a

[2] "Tensile Tests for Welds," JOURNAL OF THE AMERICAN WELDING SOCIETY, October 1930.

Fig. 3—X-Ray Diffraction Diagram of the Bare-Wire Deposit *B*, as Received. Pronounced Radial Striations

linear change of about 1% would occur when cooling, for instance, from 600° C. to room temperature (Diagram A). Since the deposit is rigidly maintained by the two heavy plates, no change in dimensions is possible, and the layer will be strained to the same amount of 1% during cooling. This is the origin of internal stresses. However, the amount of strain really responsible in producing internal stresses is less than indicated by the Diagram A. If a uniform distribution of stresses is admitted, this amount will be given by the maximum elastic strain as computed for each temperature in a short-time tensile test. This may be represented, in the case of an ordinary mild steel, by the Diagram B. As the temperature lowers, the amount of elastic strain raises, and the internal stresses become greater. The most unfavorable conditions from the standpoint of safety will occur at the neighborhood of the temperature T_0 corresponding to the intersection of the Diagrams A and B. It is for the range of temperatures between 100° and 200° C. that the ratio elastic strain over total elongation will reach its highest value in the case of an ordinary mild steel.[3] Should an additional strain at the same time be applied to the layer (e.g., if a second layer is deposited in the groove on the other side), the internal stress may rise beyond the elastic limit, and even reach the ultimate stress, provided sufficient care is not given to the deposition sequence. The danger of rupture is so much greater if the deposit contains more impurities of both macroscopical (slag occlusions, gas holes, etc.) and microscopical (oxides and nitride needles) size, i.e., if it is more brittle. That such minute discontinuities in the interior of metals may act as stress-raisers, is too well known to be discussed in detail at this time. That this may really occur during cooling, even if only microscopical impurities are present, is what has been investigated by means of X-ray diffraction method by Mr. Mathieu, at Sorbonne, at the suggestion of the author. Diagrams recorded in this way show that only deposits of high ductile quality are free from internal stresses during cooling.

In our experiments arc fusion welded specimens are built up and machined in a similar way as for the Charpy notch test (as indicated later). The upper layers with a coarse crystalline structure have been removed. The face to be examined has been polished and according to the advice of Professor J. T. Norton, of Massachusetts Institute of Technology, deeply etched with nitric acid. It is not necessary to go into greater detail regarding the technics of this new and promising method, since it has been previously described in a paper by Prof. Norton at the fall meeting of the AMERICAN WELDING SOCIETY in September 1930.[4] All that it is necessary to recall here is the significance of the X-ray diagrams. They are of two kinds: first, concentric circles, which account for the atomic arrangements and grain size of the metal; second, radial striations or "asterism," whose presence or absence accounts for the presence and absence of internal stresses in the metal. In regard to the defects in welds the latter seem to be of the utmost importance.

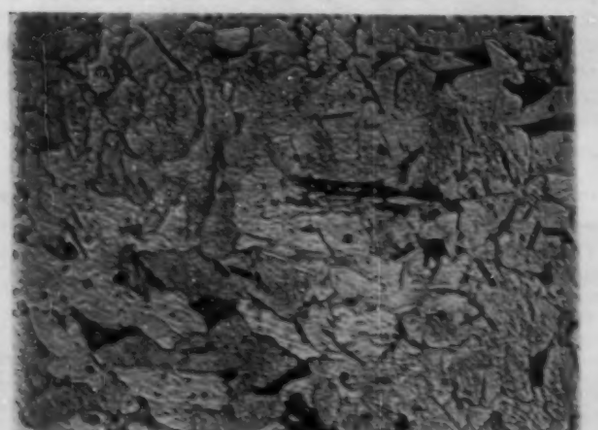


Fig. 4—Microphotograph of the Deposit *B*. Magnification 500

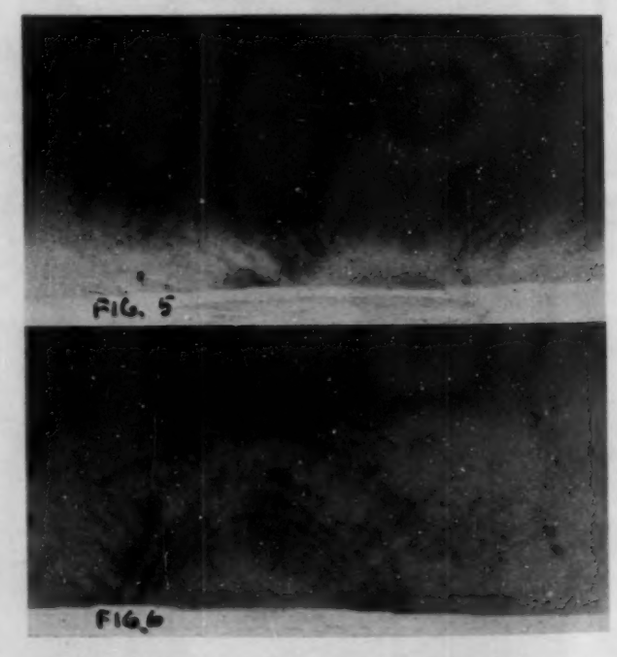


Fig. 5—X-Ray Diffraction Diagram of the Deposit *B*, Annealed. Asterism

Fig. 6—X-Ray Diffraction Diagram of the Deposit *E*, as Delivered. Radial Striations Less Pronounced Than in the Deposit *B*

Pronounced asterism has been found in bare-wire deposits, referred to as *B*, Fig. 3. Their characteristical microphotograph is shown in Fig. 4. This asterism could not be removed entirely by a short-time annealing at about 850° C. as may be seen in Fig. 5.

The asterism is less pronounced in deposits made by the coated electrode *E*, but whose protection proved not to be entirely satisfactory. This is shown in Figs. 6 and 7. A short-time annealing at 850° seems to be sufficient to eliminate asterism in this deposit (Fig. 8).

No asterism has been found in welds deposited by the heavy coated electrode *M*, which are free from microscopical and macroscopical defects (see Figs. 9 and 10).

[3] H. J. Tapsell and W. J. Clenshaw, "Properties of Materials at High Temperatures." L. London 1927.

[4] J. T. Norton, JOURNAL OF THE AMERICAN WELDING SOCIETY, September 1930.

(*b*) *Overstressing under applied loads.*—Under applied loads, overstressing due to discontinuities of shape may occur in the root of fillets. This may be deduced from extremely valuable experiments made by Dr. Mesmer of Goettingen.[5]

In these experiments models of overlapped joints with fillets placed transverse to the direction of stress have been cut out from xylonite. Stress diagrams in the throat and leg of fillets could thus be computed by means of the well-known photoelastic method of Professor Cooker.

Such diagrams indicate, Fig. 11, that, on account of overstressing occurring in the root, the throat of the fillet may be subjected to a highly uneven distribution of stresses. If this is true, a lower resistance, in pounds per sq. inch of the throat, than in direct tension may be expected for this type of fillet.

Experimental results recorded by Mr. Haas on tee-type specimens[6] (similar to those used by the Committee on Standard Tests for Welds, see series 6400 and 6500 in the November issue, 1931, of the JOURNAL OF THE AMERICAN WELDING SOCIETY) indicate that this seems to be really the case with bare-wire deposits. On every case rupture occurred in the throat of the fillet. The unit stress recorded was only 75% as great as in butt welds. The fact that this decrease in resistance may be due to the lack of ductility in the deposit, seems to be indicated in experiments performed by the author.

Fig. 7—Microphotograph of the Deposit *E*. Magnification 500

Table 1.—Resistance of Tee-Type Specimens Made from Boiler Plate (see Fig. 12)

I. Mechanical properties of the plate

No.	Area in Mm.	Yield Point Kg./-Mm.²	Ultimate Stress Kg./-Mm.²	Elongation on	%	Contraction
1	15 × 25	..	40.2	220 m./m.	20.4	53.3*
2	19.8 × 25	24.9	39.6	250 "	26	52.5**
3	19.8 × 19.9	..	39.0	..	..	.. **

* Cross to lamination.
** Along the lamination.

II. Tee-type specimens

No.	a M./.M	b M./M.	c M./M.	oH M./M.	P Metric Tons	Ultimate Stress in the Throat oH Kg./Mm.	Remarks
1	20	38	20	6.0	9.1	38	Rupture
2	20.3	38	25.2	6.4	12.6	39	through the
3	20.3	38	24.8	6.25	12.1	39	throat oA

[5] Dr. G. Mesmer, I. Internationaler Schweisstechnischer Kongress für Dampfkesselbau, July 1–3, 1931, Den Haag, p. 138.
[6] Dr. Ing. K. Haas. Theses submitted to the Technische Hochschule Carolo Wilhelmina, Braunschweig, 1930.

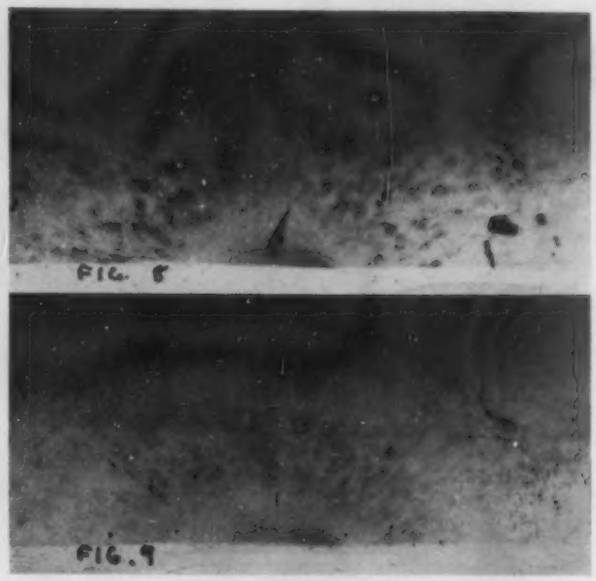


Fig. 8—X-Ray Diffraction Diagram of the Deposit *E*, Annealed. No Asterism

Fig. 9—X-Ray Diffraction Diagram of the Deposit *M*, as Received. No Asterism

For these experiments specimens have been machined from a plate of boiler quality, as shown in Fig. 12. These specimens may typify a connection with transverse fillets. They are easier to be made than the tee-type specimens previously mentioned.

It has not been possible to make them larger than 1 in. on account of the saw-cut. It is, however, believed that the breadth of specimens has little or no influence on the unit stress per sq. in.: first, nearly identical figures have been obtained with specimens 1 in. and ¾ in. in size; second, the change in breadth after rupture has been less than 5%.

All specimens, when pulled, failed in the throat oA of the hypothetical fillet oAB. The unit stress has averaged 55.2 in thousand pounds per sq. in. of the throat; the ultimate stress in direct tension gave an average of 56.5 (see Table 1). The difference between these two figures is less than 2.5%. Consequently no decrease in resistance is observed in the case of a ductile metal.*

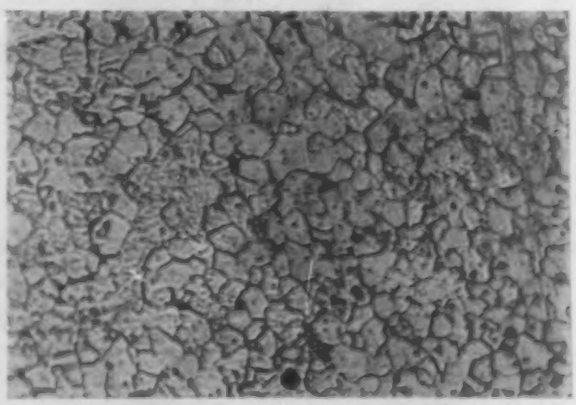


Fig. 10—Microphotograph of the Deposit *M*. Magnification 500

* Similar tests made with the heavy coated electrode *M* have given a computed stress of around 57,500 lb. per sq. in. in the throat of the fillet, which is slightly more than the ultimate stress of the base metal. This type of electrode makes, however, a deposit of at least 71,500 lb. per sq. in. Since all fractures occurred partially in the leg and partially in the weld, no conclusion can be drawn as to the efficiency of its own ductility.

Conclusions.—The following conclusions may be drawn from these experiments as compared with the tests of Mr. Haas.

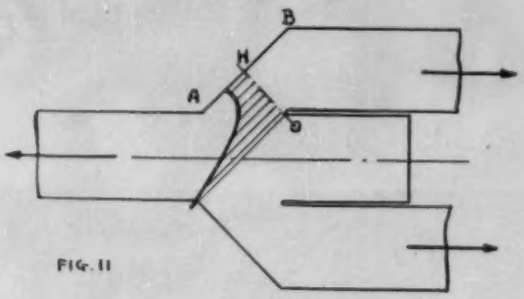


FIG. 11

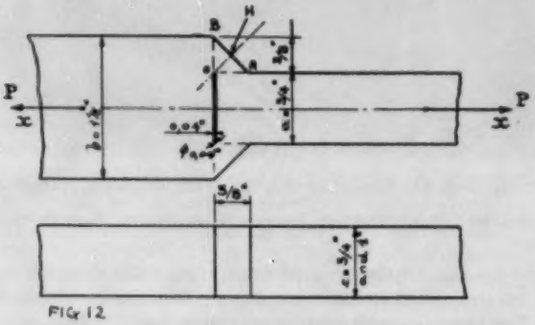


FIG. 12

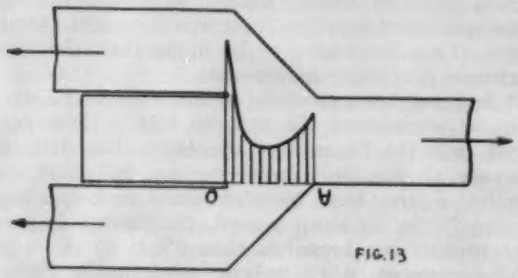


FIG. 13

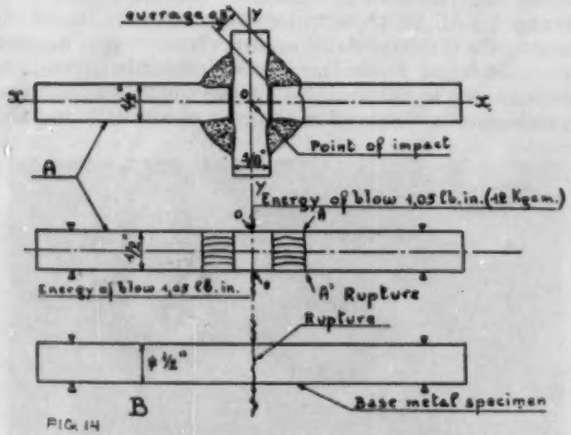


FIG. 14

Fig. 11—Stress-Repartition in the Throat of Fillet

Fig. 12—Tee-Type Specimen of Boiler Steel Plate. Indicated Dimensions Are Approximate

Fig. 13—Stress Repartition in the Leg of Fillet

Fig. 14—Welded and Unwelded Specimens for Repeated Shock Test

(1) Overstressing predicted by the experiments of Dr. Mesmer may really occur in welded connections.

(2) Overstressing may be prevented by the use of a ductile metal.

Overstressing in the zone of junction.—Moreover, overstressing in the zone of junction has been indicated by photoelastic diagrams of stresses measured in the leg of the fillets by Dr. Mesmer (Fig. 13). It is more dangerous at this point as it occurs where undercutting is also possible.

Static tests do not seem to be very appropriate to reveal overstressing: in well-designed connections rupture will, as a rule, occur outside of the joint. This does not seem to be the case with fatigue tests, since ruptures at the junction under repeated stresses have been recently reported by German investigators.[7]

If this is the case, the weakness in the junction cannot be removed by increasing the volume of the deposited metal. The weakness may be reduced by mechanical treatment, i.e., hammering, provided the deposited metal has enough ductility to permit stretching.

This has been shown by preliminary tests undertaken by the author. According to the investigations of Professor Thum,[8] residual compression stresses are developed under stretching in the top of the notches. Under applied loads, these stresses substract from the high tension stresses occurring in notched specimens, and the fatigue limit of the latter is increased.

In the experiments performed by the author, residual compression stresses have been created by hammering the junction AA' of tee-type specimens welded with the electrode M (Fig. 14). These specimens have been subjected to repeated shocks by testing in the Amsler machine. All ruptures have occurred in the junction (Fig. 15). Hammered welded specimens have supported, before rupture, the same number of alternated blows as the unwelded specimens, while unhammered welded specimens have failed with only half of this number. (See Table 2.)

Conclusion.—These experiments indicate that even in the fatigue tests a certain amount of ductility may prove to be beneficial for welded connections. The approximate amount cannot be stated at present. It is obvious that to account for the complicated state of stresses in fillets, the amount must be as high as possible in both parent and deposited metals. A similar point of view is generally held in the Western-European countries including Switzerland.[10] These countries consider a specified minimum value for ductility as of as much importance as specified minimum value for tensile strength.

Table 2.—Results of Repeated Shocks (see Fig. 14)

Specimens	No.	Impact of 12 Kg. Cm. Amsler Machine Number of Blows Before Rupture
Welded, Unhammered Junction	4	63,960
	6	89,030
	7	60,278
Welded, Hammered Junction	2	140,698
	3	125,714
	8	157,492
Unwelded Base Metal	4	155,556
	6	134,606
	7	115,728

[7] Dr. Ing. Schaechterle, *Der Stahlbau*, November 27, 1931, p. 285.
[8] Dr. Thum, *Zeitschrift des Vereins deutscher Ingenieure*, 15, October 24, 1931.
[9] D. Rosenthal, *Comptes-rendus des Séances de l'Académie des Sciences* (Paris), No. 194, p. 56.
[10] Report of the Results of Tests for Welds Performed at the "Eidgen. Materialprüfungsanstalt." Zurich, May 1931.

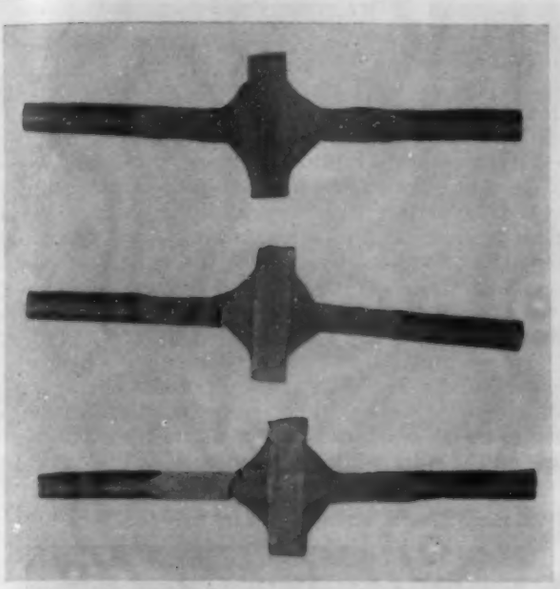


Fig. 15—Welded Specimens Fractured

Measurement of Ductility

Since the effect of localized stresses on welds is to be measured, the impact notch test seems to be the most suitable for this purpose.

This idea has been developed in a paper presented by Messrs. H. Dustin and D. Rosenthal at the International Meeting for Testing Materials held at Zurich in September 1931, Section A.

This paper shows:

(1) That consistent results may be obtained when the specimens are carefully prepared (Fig. 16).

(2) That figures recorded from the Charpy notch test agree sufficiently well with the results of elongation as measured in the ordinary tension test (Fig. 17).

Although no systematic tests are known by the author to support any correlation between a notch test and a bend test, his own investigations of the bend tests make him believe that (in spite of some exceptions which have been reported) there is a definite correlation provided the measurement of the outside fiber elongation during bending is restricted to the deposit.[11,12]

Conclusions

The following general conclusions may be drawn from the above-reported experiments:

1. Overstressing may occur in welded connections during shrinkage as well as under applied loads in service.

2. To prevent overstressing, both the parent and deposited metals must be ductile. The more ductile they are, the safer the structure.

3. The notch test seems to be the most suitable for measuring the effect of overstressing in welds.

[11] D. Rosenthal et H. Michel, *Journal of the Société Belge des Ingénieurs et Industriels*, t. XI, no. 5, July 1931.

[12] Report of the Committee for Standard Tests for Welds, JOURNAL OF THE AMERICAN WELDING SOCIETY, November 1931.

Fig. 16—Actual Figures for Impact Tests Made with Charpy Notch 5 M./m. Deep and Mesnager Notch 2 M./m. Deep

(*a*) Deposit *B*
(*b*) " *M*

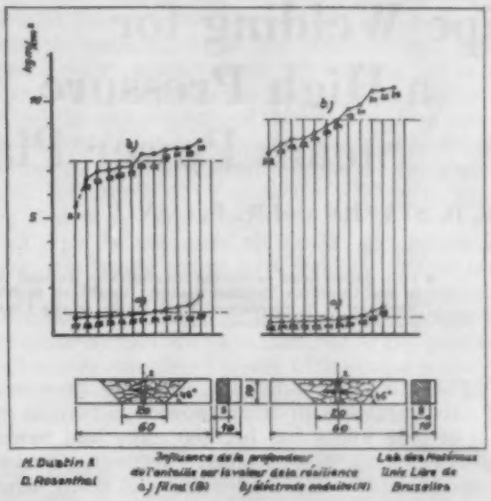

H. Dustin & D. Rosenthal
Influence de la profondeur de l'entaille sur la valeur dans résilience
a) fil nu (B) b) électrode enduite (M)
Lab des Matériaux Univ. Libre de Bruxelles

FIG. 16

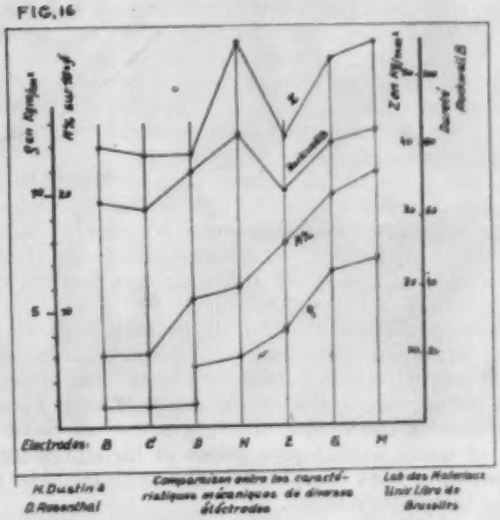

Electrodes B C D H E G M
H. Dustin & D. Rosenthal
Comparaison entre les caractéristiques mécaniques de diverses électrodes
Lab des Matériaux Univ. Libre de Bruxelles

FIG. 17

Fig. 17—Mechanical Properties of Deposits Made with Different Kinds of Electrodes:

Z—Ultimate Stress in Kg./mm.² Rockwell B—Hardness
A—Elongation in %
ρ—Charpy Notch Figures in Kg./c.²

Acknowledgments

The author wishes to express acknowledgment to the Belgian Company, "La Soudure Electrique Autogene" (Arcos process) á Bruxelles, for assistance which has enabled him to perform the experiments reported in this paper.

Pipe Welding for a High Pressure Steam Power Plant

By E. B. SEVERS *and* W. P. GAVIT

✦This paper was presented during the Annual Meeting of the American Welding Society, April 27th to 29th, New York, by E. B. Severs and W. P. Gavit, of the United Engineers & Constructors, Inc.

WITH the increasing use of higher pressures and temperatures in steam power plants the matter of pipe joints has become more and more of a problem. The ordinary flanged joint with a gasket was quite satisfactory for the pressures and temperatures in vogue ten years ago when steam pressures seldom exceeded 300 lb. per square inch and 650° was considered high temperature. Today with 450 lb. per square inch regarded almost as a lower limit of pressure and with temperatures ranging from 750° to 850° and 1000° not out of the question, the simple gasketed flanged joint is no longer satisfactory.

Special types of joints have been designed, many of which are satisfactory as to tightness and permanence. However, special materials must be used to hold the pressures at elevated temperatures and the thickness and weight of the joints and their cost become excessive.

Welding offers a solution of the high pressure, high temperature pipe joint problem. Experience has shown that a properly made welded joint is stronger in the weld than outside it. However, so much depends upon the expertness of the welder, that engineers have been hesitant in using welded pipe joints in high pressure and temperature work except where the welds could be made in the fabricator's shops.

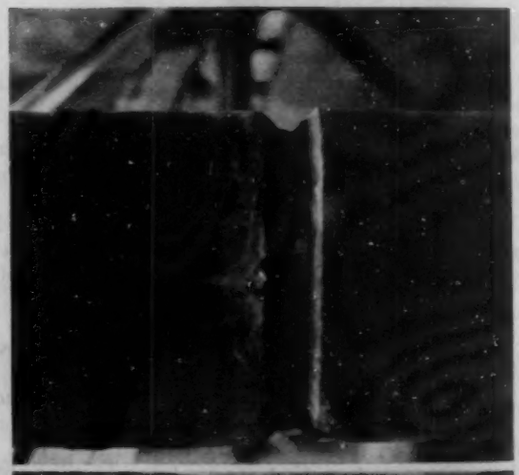
The Public Service Electric & Gas Company of New Jersey have just completed the installation of a boiler and turbine in their Burlington Generating Station. This equipment operates at a pressure of 730 lb. per square inch and a temperature of 860° F. There also is a secondary steam system operating at 200 lb. per square inch with a maximum temperature of about 600° F. It was decided to use welded joints throughout both the 730- and 200-lb. steam systems and also for the boiler feed system. Only where pipe connected to valves, turbine and boiler outlets, etc., were flanged joints to be used. For the smaller diameter pipe, screwed fittings and valves were used. The screwed joints were made up tight and then welded.

The reasons for adopting welded construction were, first, to secure a permanently tight job and, second, to determine whether there would be a saving in cost with this type of joint as compared with flanged joints. Though welding has been used quite extensively in power piping installations, its use in this case was somewhat of an experiment because of the combination of high temperature and pressure. No similar job had ever been done but the general status of the welding art, the classes of work that had been satisfactorily accomplished and the knowledge of the problems involved gave reasonable assurance that this work could be safely done in this way.

The pipe for the 730-lb. system is seamless steel tube in sizes up to 16 in. The wall thickness runs from $^{11}/_{16}$ in. for 6 in. up to $1^1/_2$ in. for the 16-in. pipe. The pipe was made up in the fabricator's shop into sections as long as could be shipped and handled in erection. This permitted making many of the welds in the shop. The shop welds were made by the electric arc weld process and were then annealed by placing the entire piece in an annealing furnace. All field welds were made by the oxyacetylene process and locally annealed in a manner which will be described later.

It is not practical to do more than apply a hydrostatic pressure and hammer test to work of this character. It is therefore necessary to use special caution in selecting men to do the work and to keep as close a check as possible on the work while in progress.

Fig. 1—Joint Ready for Welding



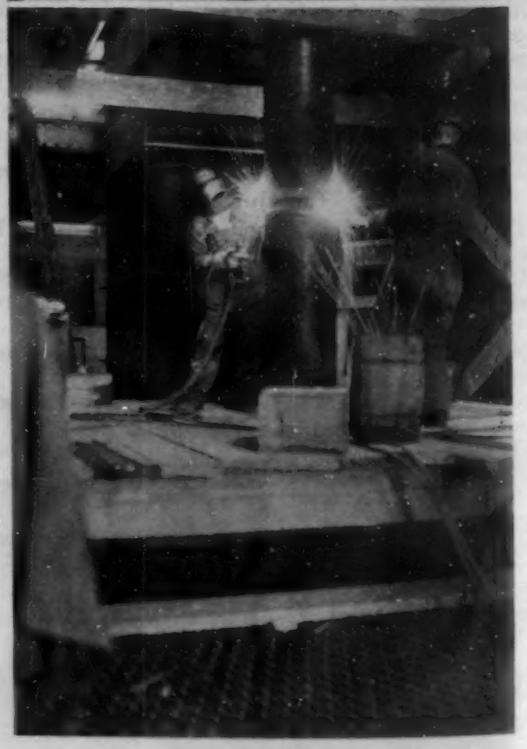


Fig. 2—Welding in Process

Fig. 3—Making a Position Weld

The field welds had to be made in various fixed positions and some required that the work be carried on continuously for twenty-two hours. Normal fatigue would tend to make even the best men less careful toward the end of such a long period. In order to be sure that the men engaged to do the welding were fully qualified both as to craftsmanship and personal qualifications, the qualifying examinations were carefully worked out with the Hartford Steam Boiler Inspection and Insurance Company.

For qualification the welders were required to make single V welds in $1^1/_2$-in. flat plate. In the qualification tests the plates were aligned in a vertical plane so that the welders were required to make what is termed a horizontal weld. This is one of the most difficult welds to execute properly and gives an index of the operator's ability to weld in all positions. It would have been better to have let the men qualify on pieces of the pipe that were to be used on the job. However, the seamless tube for the high pressure system was purchased in Europe to very close lengths and no extra pieces were available for this purpose. Coupons cut from the welded plate were annealed and subjected to tensile, ductility, nick-break and other tests. It was at first intended to establish the Class I test requirements of the A. S. M. E. Unfired Pressure Vessel Code for qualifying the welders. These requirements were found to be both impracticable and unnecessarily rigid. A minimum of 45,000 lb. per square inch was therefore accepted for the reduced section tensile test and a minimum of 12% for the ductility requirements. Two welders were qualified for the heavy wall high pressure piping. Another welder was used to assist in the work who had qualified on thinner material but had not met all the requirements established for the heaviest wall piping.

Figure 1 shows a joint ready for welding. The procedure in making the welds was first to lay in the bottom of the V all the way around and then two welders, starting at a point, would work in opposite directions building up the full depth as they worked around the periphery of the pipe. Figures 2 and 3 show the welding in process and Fig. 4 shows a completed weld.

On all pipe for pressures of 200 lb. per square inch and over, reinforcing straps were welded. These straps were bent so their two ends could lie flat against the pipe on either side of the weld while in the middle they did not make contact with the material of the pipe weld. Figure 5 shows completed joints with straps welded on.

Figure 6 shows an interesting design of pipe hanger used in connection with these welded joints.

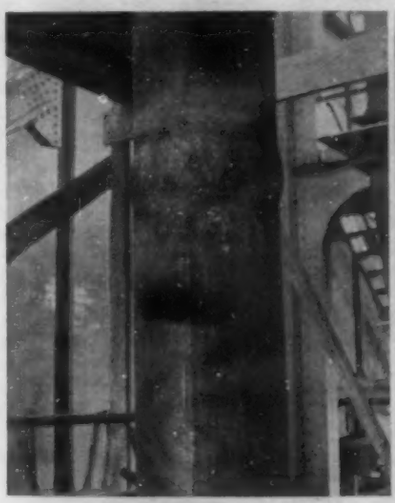


Fig. 4—Completed Weld

Fig. 5—Completed Joints with Straps Welded on

Fig. 6—Pipe Hanger

The problem of properly annealing the joints made in the field was met by the construction of a special furnace

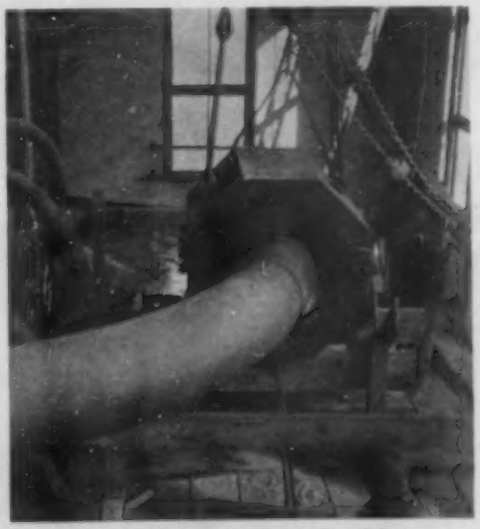


Fig. 7—Furnace Applied to Pipe Joint

that could be applied to the joint in place. This furnace was made up of steel plate and filled with asbestos.

It was applied to the joint as shown in Fig. 7 and was fired with two fuel oil burners. The joint was heated to about 1500° F. heat being applied for about 2 hours. The burners were then removed, the furnace packed full with asbestos and left so overnight. This method was used only on the high pressure piping system. The pipe for the 200 lb. per square inch system was stress relieved by heating to a cherry red and cooling in still air.

After the joints were completed they were hydraulically tested with a pressure of 1500 lb. per square inch. All joints were hammered with a heavy sledge while under pressure and no leaks developed in any of these made in the field.

An uninterrupted flow of gas was, of course, essential to the successful accomplishment of the work.

The authors wish to express their appreciation of the assistance received in the preparation of this paper from Mr. Carl Tyler of the Hartford Steam Boiler Inspection and Insurance Company, and for the photographs which were taken by Mr. Louis C. McNutt.

Modern Spot and Relief or Projection Welders and Their Application to Production Problems

By P. W. FASSLER

†Paper was presented at Annual Meeting, American Welding Society, April 27th to 29th, New York, by P. W. Fassler, Consulting Engineer, Detroit.

THE principle of spot welding was evolved from the butt welding process which has been known to industry from as far back as 1886. The spot welder was first used in production applications about the year 1905 and grew so rapidly in popularity during the period of 1905 to 1910 that one could say without exaggeration that the spot welders in use exceeded the butt welders by a ratio of five to one.

FIG. 1

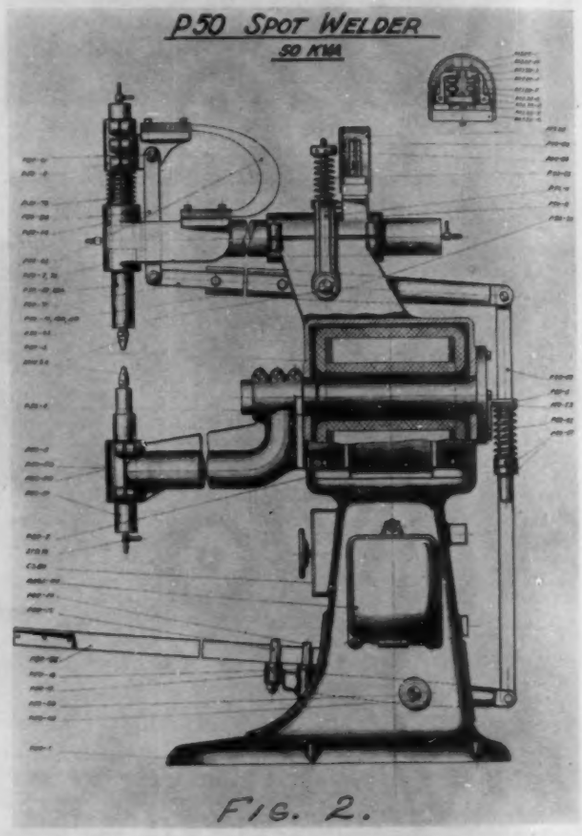


FIG. 2.

The spot welder continued to enjoy its popularity until the year 1924 when the projection welding method was introduced. This new method so intrigued the welding engineers that they lost interest in spot welders and devoted most of their efforts to applying projection welding methods wherever possible. Today there are many welding experts who feel that it is unwise to devote time or money in further developing the spot welder because they feel that it cannot possibly compete with the projection welder.

The writer is entirely out of sympathy with this viewpoint for he feels that there are certain applications to which the spot welder is particularly suited. The spot welder will always be found on small production operations for the reason that the projection welder is essentially a high production machine. Furthermore, the initial cost of the projection welder is too high to allow it to enter into competition with the spot welder in this field.

One argument advanced in favor of the projection welder over the spot welder is based on the fact that the

human element is entirely eliminated in the operation of the projection welder, while it is present to a great extent in the operation of the spot welder. Recent developments in spot welder control devices will eliminate this objection. It is now possible to control the time that current is applied to the weld and, by interlocking devices, to insure that the operator continues to apply pressure until the weld is properly made. The spot welder has developed from a relatively crude device (Fig. 1) to an elaborate high speed production tool (Fig. 2).

There are two general principles used in spot welding, namely, the parallel principle and the series principle. All conventional spot welders incorporate the parallel method wherein the lower arm is one pole and the upper arm is the other pole. The series method is found in special applications of spot welding where it is either impossible or impractical to use the conventional method. In the series method two spots are made simultaneously as illustrated in Fig. 3. A_1 and A_2 are the electrodes, B_1 and B_2 are the welding stock and C is the bridge to facilitate the passage of current. This bridge is usually made of copper. In some applications it is impossible to incorporate this bridge and we must depend on the current-carrying ability of the lower section of the welding stock.

In practice the series method is not used as much as its qualities warrant. In analyzing the properties of this method we find that it gives us a most perfect weld as the current leakage is reduced to a minimum. Unfortunately space and time limitations prevent us from discussing this method as thoroughly as we would like to. But we will say that there are many welding jobs where it is impossible to use a lower electrode and so it is necessary to resort to the series method on both stationary and portable welder applications.

Spot welders can be subdivided into two general classes, namely, the conventional stationary type (Fig. 2) where the work is brought to the welder; and the portable type where the machine is brought to the work (Fig. 4). In the first class are included the hand operated, foot operated, air operated and motor driven machines. In the second class are included the portable spot welders which are either hand or air operated; semi-portable spot welders (Fig. 5) which have stationary transformers and welding tools that are movable within the range of the flexible cables connecting the welding tools to the transformers; the so-called "welding bar" wherein the welding tool is used as a lever with the upper electrode, the fulcrum, and the lower electrode, the support for the welding stock (Fig. 6).

All spot welding equipment functions with the fundamental resistance welding principle, namely, heating and squeezing. This is accomplished by first applying sufficient mechanical pressure to insure electrical contact; second, allowing current to flow through the metal to be welded until it has reached the proper temperature; third, increasing the pressure to insure the proper bond. Because of the high speed at which it is operated, it is most essential that all vital parts of the spot welder be properly coordinated. The pressure controlling spring and moment switch must be kept in adjustment as it is most important that the correct amount of pressure be applied on the welding stock before the current is sent through the electrodes. The electrodes must be kept trimmed to the proper curvature necessary to localize the heat. If a magnet switch is used in conjunction with a spot welder, it should receive regular inspection. Failure of the magnet switch to open the circuit before mechanical pressure is entirely released on the electrodes means a burned or crystallized weld which cannot be depended on.

Trouble with spot welding increased proportionately with the number of spot welding machines put into production. The production men demanded higher speeds and more dependable welds from the spot welders. This placed the welding machine designers and manufacturers in a dilemma as they knew the speed of a spot welder was limited.

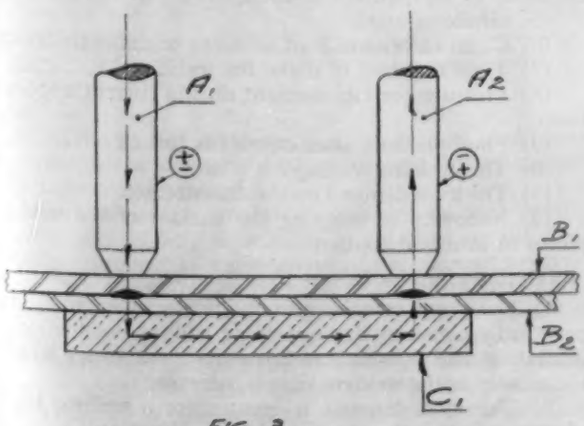


FIG. 3

FIG. 4

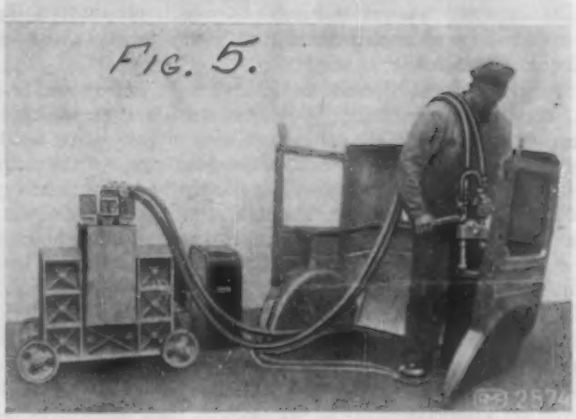


FIG. 5.

We already had spot welding machines in production at that time which made up to 250 spots a minute but they tired out the operators, who, in turn, tried to readjust the machines to make it easier for themselves. In other words, the switch pressure spring was loosened. This brought the spot welders entirely out of control as we had to depend on the operator.

Automatic (motor driven) spot welders did not help us to any great extent as the electrode wear was too rapid and, because of this, brought the welding time and pressure out of cycle. Experimental work was done to a considerable extent in multiple spot welding but without satisfactory results.

In order to overcome this situation we went back to an old method that had been discovered in 1903 and which was called "relief" welding. At the time of this discovery the possibilities of this method were not fully recognized but about twenty years later when the electric resistance welding machine had been more fully introduced it was an entirely different situation. We started to build special machines for this so-called "relief" welding process. At first we built machines for welding five spots or embossments in one stroke, then for ten spots, etc. We soon realized that we had solved this troublesome problem.

Not only did this new method offer much higher production opportunities but, also, it enabled us to create automatically operated machines which eliminated the human element and insured that every weld was under absolute control.

Since its introduction in 1924, the projection welding method has gained in popularity until it now ranks in importance above all other methods of resistance welding. Projection welders or welding presses as they are often called are to be found in practically every industry of any importance where the volume of production warrants their use. Welded stamplings are fast replacing forgings. This change is particularly noticeable in the automobile industry.

Unfortunately the knowledge of the theory of operation and proper maintenance of these machines has not spread throughout the industry as fast as their use and popularity have increased. This condition has made it hard on manufacturers of welders as they are forced to make many service calls that would be unnecessary if the men responsible for their care were as familiar with welders as they are with other machine tools operating in their plants.

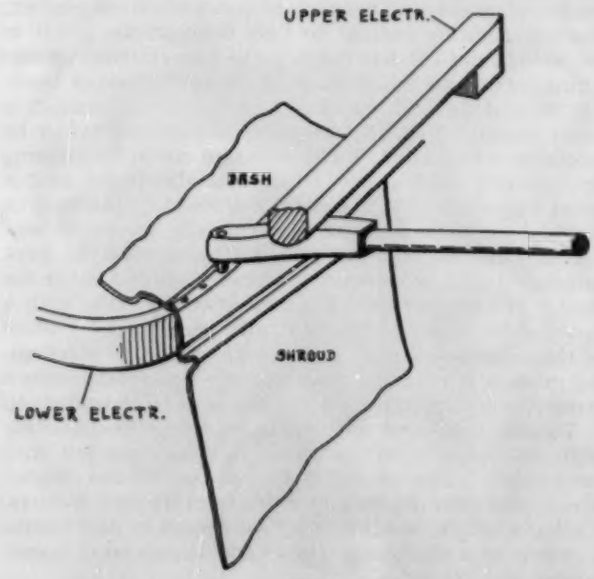


Fig. 6

In his contact with various men in industry holding relatively high positions, the writer has discovered that many are not as familiar with welders and their operation as they should be. The writer feels that too much missionary work cannot be done to change this condition. If part of the subject-matter in this paper seems too elementary to some, the writer hopes they will be tolerant so that he can reach those who can use the information.

In spot welding, the electrodes are depended on to properly localize or concentrate the current; while in projection welding, embossments in the welding stock serve this function. While a spot welder is a comparatively simple machine, a projection welder or welding press is a relatively complicated machine, wherein the mechanical and electrical parts are nicely coordinated to produce the desired results. Every projection welding job must be closely studied with regard to kv-a requirements, proper mechanical pressure, cam design to insure the correct balance between heat and pressure application, electrode design to insure proper distribution of current on all embossments and probable speed of production of the machine when in operation.

All projection welds are made along similar lines, i.e., a limited amount of pressure during current application, followed by a pressure of many thousand pounds before the welding stock has had time to cool below the welding temperature. Welder manufacturers use various methods to effect these results. All motor-driven machines have a cam with either a lever action or toggle action between the cam and the electrodes. The writer prefers the toggle action. Air-operated machines can have either a direct coupling from the air cylinder to the electrodes or can have a lever or a toggle between the air cylinder and the electrodes.

The designer does not experience any particular difficulties on the mechanical features of his machine but to anticipate the electrical requirements for any given job is a more difficult task due to the many variables involved. Much experimental and research work has been done to determine the several factors involved and their relation to each other.

The major factors involved are:

(1) Area of embossments.
(2) Number of embossments to be welded in one operation.
(3) Thickness or height of embossments.
(4) Thickness and area of metal pieces under the electrode to be welded together.
(5) Grade of steel.
(6) Gram calories of heat required to make the weld.
(7) Time required to make the weld.
(8) Pressure per embossment during current application.
(9) Final pressure after current is turned off.
(10) The welding voltage.
(11) The kv-a demand on the transformer.
(12) Necessity of bringing the surface of the welded pieces in intimate contact.

Relation of major factors to each other.

(1) The gram calories required for a given weld are practically constant if the welding time is not too long. Radiation and conduction introduce heat losses which are greater as the welding time is increased.

(2) The kv-a demand is greater for a welding time of short duration than for one of longer duration.

Fig. 7

Embossments in:		Welded to:											
		20GA—0.0375		18GA—0.0500		16GA—0.0625		11GA—0.125		7GA—0.1875		3GA—0.250	
Gage	Thickness	Diam. of Emb.	Height of Embossment	Diam.	Height	Diam.	Height	Diam.	Height	Diam.	Height	Diam.	Height
20GA	0.0375	5/16"	0.040–0.050	5/16"	0.040–0.050	5/16"	0.040–0.050	5/16"	0.040–0.050				
18GA	0.0500	5/16"	0.030–0.040	5/16"	0.030–0.040	5/16"	0.040–0.050	5/16"	0.040–0.050				
16GA	0.0625	5/32"	0.030–0.040	5/32"	0.030–0.040	5/32"	0.030–0.040	5/32"	0.040–0.050	5/16"	0.040–0.050	5/16"	0.040–0.050
11GA	0.125	5/32"	0.030–0.040	11/64"	0.030–0.040	11/64"	0.030–0.040	11/64"	0.040–0.050	5/16"	0.040–0.050	5/16"	0.040–0.050
7GA	0.1875	5/16"	0.030–0.040	11/64"	0.030–0.040	11/64"	0.030–0.040	5/16"	0.040–0.050	5/16"	0.040–0.050	5/16"	0.040–0.050
3GA	0.250	5/16"	0.030–0.040	5/16"	0.030–0.040	5/16"	0.030–0.040	5/16"	0.040–0.050	5/16"	0.040–0.050	5/16"	0.040–0.050
13GA	0.093	5/32"	0.030–0.040	11/64"	0.030–0.040	11/64"	0.030–0.040	11/64"	0.040–0.050	5/16"	0.040–0.050	5/16"	0.040–0.050

(3) The welding voltage must be increased as the welding time is decreased. This is not a straight line function. A good empirical rule is to increase the welding voltage about 15% for a 40% increase in welding time. The welding voltage must be increased as more embossments are added to compensate for the voltage drop in the secondary circuit.

(4) The kilowatts, kilowatt seconds and welding voltage are all affected when it is necessary to bring the welding stock in intimate contact.

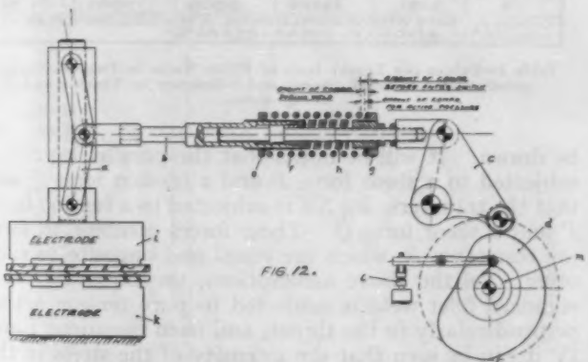


FIG. 12.

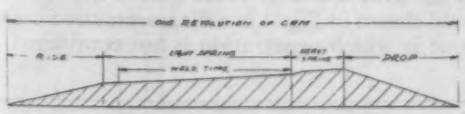


FIG. 11.

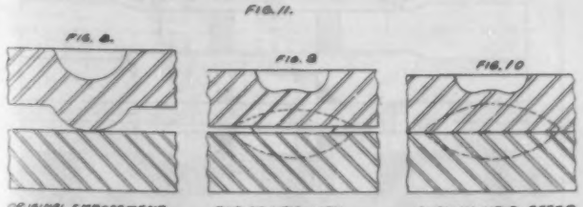


FIG. 8.
FIG. 9
FIG. 10
ORIGINAL EMBOSSMENT SHOWING POSITION AFTER INITIAL PRESSURE IS APPLIED AND BEFORE WELD IS STARTED [LIGHT SPRING]
END OF WELD WITH INTERMEDIATE PRESSURE [LIGHT SPRING]
SHOWING WELD AFTER UPSETTING. [HEAVY SPRING]

(5) The welding voltage, welding current and kv-a increase as the pressure per embossment during current application is increased.

The relationships tabulated above can be used in only a most general way as a guide in determining the electrical requirements for a given job of embossment welding. There are too many uncontrollable variables and conditions that cannot be anticipated to use any rigid set of rules. The distance the electrodes must be placed from the transformer has an important bearing on the welding voltage and kv-a. The quantity of ferrous metal in the influence of the welding circuit has an important bearing on the job. The shape and spacing of embossments must also be considered.

A welding job that requires electrodes centered 24 in. from the transformer with ten embossments wherein the two pieces of metal must be brought in intimate contact, will require a higher welding voltage, and will use more kv-a and kw. than a job with ten embossments that can be welded close to the transformer and where there is no necessity of bringing the surfaces of the welding pieces within 0.001 in. of each other.

Past experience in similar applications is the best guide the designer has in anticipating the electrical requirements of a machine for some particular job. The average welding expert will invariably borrow from knowledge gained from jobs successfully concluded rather than depend on rules. Not that the designers lack respect for rules and laws but rather the unknown factors such as radiation losses, induction losses, resistance of the welding stock and many variables impossible to anticipate or tie down make it advisable to use past experience in preference to rules. Figure 7 shows embossment characteristics in relation to the thickness of the welding stock. These data have been accumulated from the experience of many years. No claim is made that the values given are inflexible and that no other dimensions can be used with success but they are safe values and in most cases give the desired results.

The following typical welding job will illustrate how the designer uses his theory and experience. The problem is to weld two pieces of one-eighth inch cold rolled steel with five embossments. From Fig. 7 the embossments are determined to be 11/64 in. in diameter with a height of 0.040 in. to 0.050 in. Past experience would advise pressure per embossment during current application of 150 to 200 lb. with a final upsetting pressure of approximately five times this amount. With the electrodes located relatively close to the transformer we would expect to use a welding voltage of seven to nine volts. To determine the kilowatt capacity of our welder we could estimate the gram calories required and from Joule's Law of Heat Relation to Work and an assumed welding time arrive at a theoretical value; but for simple problems such as this we would use a value of seven kilowatts per embossment. Anticipating a high rate of production on this job, we would use a safety factor of two and one-half which would bring the capacity of our machine up to ninety kilowatts.

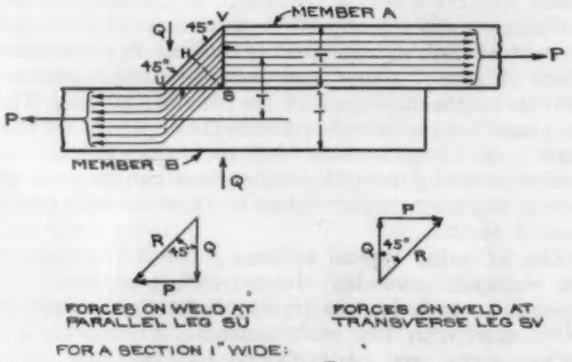
A properly adjusted machine would produce a weld with the various stages illustrated in Figs. 8, 9 and 10. Figure 11 is a graphical presentation of a complete welding cycle of which Figs. 8, 9 and 10 are the first, second and third stages, respectively. Figure 12 depicts the major mechanical features to produce this cycle. It is most important that the welding current be killed at the period of the welding cycle shown in Fig. 9. Should the welding current be left on during the third stage of the weld the demand on the transformer in amperes and kv-a would be approximately doubled without improving the character of the weld in the least.

The Experimental Determination of the Values of Fillet Welds in Tension

By LEON C. BIBBER

†Paper was presented at the Annual Meeting of the American Welding Society, April 27th to 29th, New York. Mr. Bibber is Senior Welding Engineer, Bureau of Construction and Repair, Navy Department.

AT THE spring meeting of this Society in 1930 the writer presented a paper in which he advanced certain ideas as regards the method of calculating the stresses in fillet welds. The subject-matter of this present paper is the experimental verification of that method.



FOR A SECTION 1" WIDE:

I. STRESS IN BASE METAL $= \frac{P}{T}$

II. RESULTANT FORCE R IN THROAT OF WELD $= \frac{P}{\sin 45°} = 1.414\,P$

III. AREA OF THROAT $= T \cos 45° = .707\,T$

IV. STRESS IN THROAT $= \frac{R}{SH} = \frac{1.414\,P}{.707\,T} = \frac{2P}{T}$

V. VALUE OF BASE METAL = 60,000 #/□" T

WHEN THE WELD IS STRESSED TO 36,000 #/□" THE BASE METAL IS STRESSED TO 18,000 #/□"

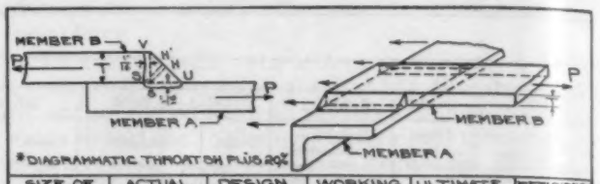
VI. VALUE OF LEG = 25,000 #/□" T

VII. THEORETICAL EFFICIENCY $= \frac{18{,}000\ \#/\square" \cdot T}{60{,}000\ \#/\square" \cdot T} = 30\%$

Fig. 1—Diagrammatic Fillet Weld in Tension

Figure 1 shows a diagrammatic fillet weld in tension. This figure was shown in the earlier paper; the transverse forces Q were not shown on the sketch at that time but they were used in the vector diagrams.

A body is not in equilibrium unless the algebraic sum of all external forces and moments is zero. In the diagrammatic fillet weld shown in Fig. 1 the forces P are balanced but the couple PT is not balanced and the joint is not in equilibrium. Additional external forces Q are necessary to balance the couple PT before the joint can be considered in equilibrium and before equilibrium diagrams can be drawn. The exact location at which these forces Q act, and therefore their intensity, is difficult to determine but the simplest procedure is to assume that the forces Q are equal to each other and equal to the forces P, and that they act at a distance T from each other. On this assumption, the vector diagrams shown in Fig. 1 can



SIZE OF WELD AND THICKNESS OF BASE METAL "T" (INCHES)	ACTUAL LENGTH OF THROAT S'H' (INCHES)	DESIGN ULTIMATE VALUE PER LINEAR INCH OF WELD, IN DIRECTION P	WORKING VALUE PER LINEAR INCH OF WELD, WITH FACTOR OF SAFETY OF 4.	ULTIMATE VALUE OF BASE METAL IN DIRECTION P AT 60,000 LBS. PER SQ. IN.	EFFICIENCY OF WELD IN TENSION OR COMPRESSION (PER CENT)
1/8	*.1061	2,700	675	7500	36.00
3/16	*.1591	4,051	1012	11250	36.00
1/4	*.2122	5,401	1350	15000	36.00
5/16	*.2652	6,751	1688	18750	36.00
3/8	.3094	7,876	1969	22500	35.00
7/16	.3536	9,001	2250	26250	34.29
1/2	.3977	10,124	2531	30000	33.75
9/16	.4419	11,249	2812	33750	33.33
5/8	.4861	12,374	3094	37500	33.00
11/16	.5303	13,499	3375	41250	32.72
3/4	.5745	14,624	3656	45000	32.50
13/16	.6187	15,750	3938	48750	32.31
7/8	.6629	16,875	4219	52500	32.14
15/16	.7071	18,000	4500	56250	32.00
1	.7513	19,125	4781	60000	31.88
1 1/16	.7955	20,250	5062	63750	31.76
1 1/8	.8397	21,375	5344	67500	31.67
1 3/16	.8838	22,501	5625	71250	31.58
1 1/4	.9281	23,626	5906	75000	31.50
DESIGN ULTIMATE STRESS IN WELD METAL IN TENSION & COMPRESSION = 36,000 #/□"; IN PARALLEL SHEAR = 25,452 #/□"					

Table 1—Values per Linear Inch of Fillet Welds in Tension, Compression and Parallel Shear, and Efficiency in Tension and Compression

be drawn. It will be noted that the parallel leg SU is subjected to a shear force P and a tension force Q and that the transverse leg SV is subjected to a tension force P and a shear force Q. These forces combine to form the resultants R, which are equal and opposite to each other. On the above assumptions, the throat SH of a standard fillet weld is subjected to pure tension acting perpendicularly to the throat, and from equations I and IV it can be seen that the intensity of the stress in the throat of the weld is exactly twice that in the base metal.

The weld shown in Fig. 1 is a diagrammatic fillet weld, that is, one in which penetration is not considered. All

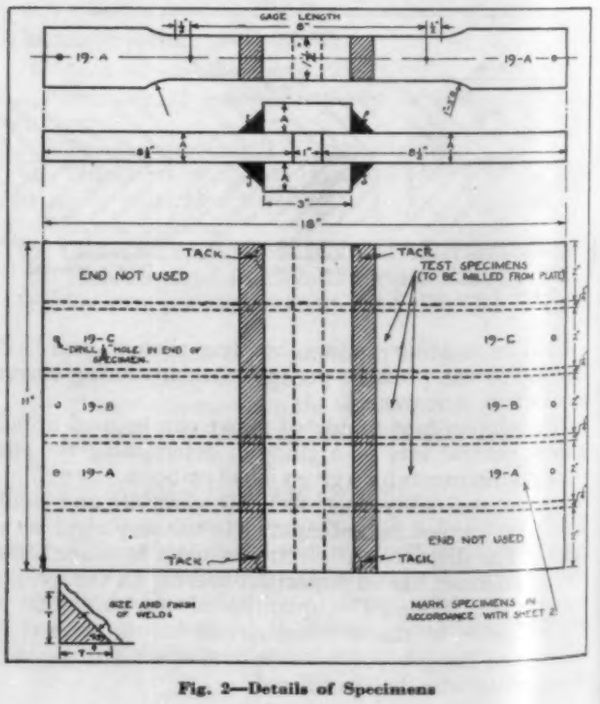


Fig. 2—Details of Specimens

welds, however, have penetration and $^1/_{16}$ in. has been selected as a standard penetration. The increase in the throat due to penetration can be seen in Table 1 and the length including penetration of the throat of the different sizes of fillet welds is tabulated in column 2.

It will be noted that the effect of penetration is relatively less on the larger sizes of welds, and also that on the very small welds the increase in throat length due to penetration is not permitted to exceed 20%.

It has been contended by some that good penetration is not often obtained at the root of the weld and for this reason it would be better not to consider penetration in calculating the values of fillet welds. Such a procedure would penalize the weld twice, because the likelihood of bad workmanship is already taken care of by the use of a low design ultimate strength. It is more logical to let one factor of safety take care of all phases of bad workmanship.

In column 3 of Table 1, the ultimate values per linear inch of the different sizes of fillet welds are given. These values were calculated on the theory given in Fig. 1, using a design ultimate strength of 36,000 lb. per sq. in. In column 4, working values, with a factor of safety of 4, are given. The values of the base metal and the efficiency of the single weld are shown in the last two columns. All of the above values apply only when the transverse forces Q are supplied to keep the joint in equilibrium.

In order to prove the values given in Table 1 and hence the theory on which they were calculated, the experiment shown in Fig. 2 was undertaken.

Double-strapped, open-butt joints of the type shown in Fig. 2 were made up. The thickness of the plates and the straps, and the sizes of the welds were varied. All welds were machined accurately to size. This was accomplished by etching the side of the specimen so that the profile of the weld and its penetration were clearly apparent, and then laying off the weld to the theoretically correct size and shape.

The list of specimens is given in Table 2. It will be noted that the weld sizes range from $^1/_{16}$ in. to $1^1/_4$ in. The $^1/_{16}$-in. size proved impractical; it was not strong enough to withstand handling and machining. The plate and strap thicknesses ranged from $^1/_2$ in. to $1^1/_2$ in. In every case the ratio of weld size to plate size was chosen so that failure would be forced to occur in the welds. Three specimens of every size were made so that average values could be obtained.

The welds were made with bare medium steel electrodes which in many tests have been depositing metal having an ultimate tensile strength of about 60,000 lb. per sq. in.

The appearance of six of the finished test specimens is shown in Figs. 3 and 4. It is not necessary to show the whole series; only the extreme sizes are given in Figs. 3 and 4.

The fractures of all the specimens, however, are given in Figs. 5 to 13, inclusive.

Little can be seen on the smaller welds because of the relatively great influence of a flaw but the fractures of the larger specimens are very interesting. In the welds shown in Fig. 11, it will be noted that the fractures of specimen X are at approximately a 45-degree angle. The fractures of the left-hand strap of specimens Y and Z are likewise at 45°, but the fractures of the lower right-

Table 2—List of Specimens

Mark	No. Req.	Finished Size of Weld "T" In.	Thickness of Plate "A" In.	Description	Material
19-A, 19-B, 19-C	1	$^1/_{16}$	$^1/_2$	Finished Test Specimen	Mild Ship Steel
19-D, 19-E, 19-F	1	$^1/_8$	$^1/_2$		
19-G, 19-H, 19-J	1	$^3/_{16}$	$^1/_2$		
19-K, 19-L, 19-M	1	$^1/_4$	$^1/_2$		
19-N, 19-P, 19-Q	1	$^3/_8$	$^1/_2$		
19-R, 19-S, 19-T	1	$^1/_2$	$^3/_4$		
19-U, 19-V, 19-W	1	$^5/_8$	$^3/_4$		
19-X, 19-Y, 19-Z	1	$^3/_4$	1		
19-AA, 19-BB, 19-CC	1	1	$1^1/_4$		
19-DD, 19-EE, 19-FF	1	$1^1/_4$	$1^1/_2$		

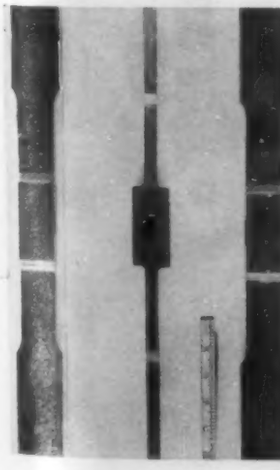


Fig. 3—Specimens *D*, *E* and *F*. $^1/_8$-In. Welds $^1/_2$-In. Plate

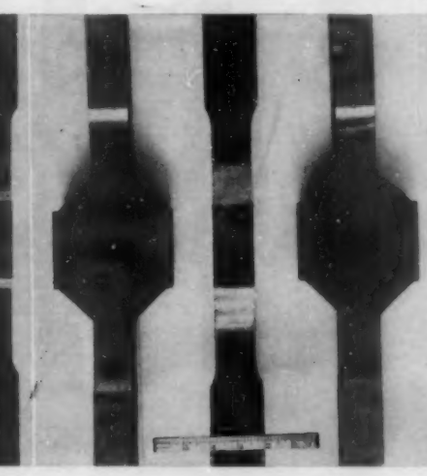


Fig. 4—Specimens *DD*, *EE* and *FF*. $1^1/_4$-In. Welds $1^1/_2$-In. Plate

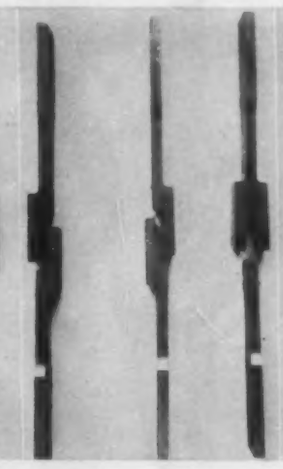


Fig. 5—Fracture of Specimens *D*, *E* and *F*. $^1/_8$-In. Welds $^1/_2$-In. Plate

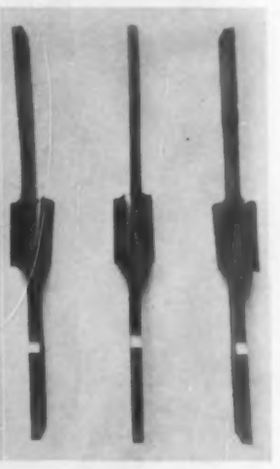


Fig. 6—Fracture of Specimens *G*, *H* and *J*. $^3/_{16}$-In. Welds $^1/_2$-In. Plate

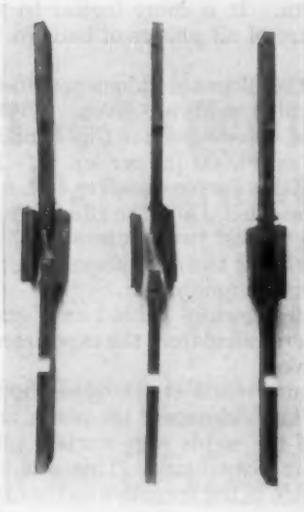


Fig. 7—Fracture of Specimens *K*, *L* and *M*. 1/4-In. Welds 1/2-In. Plate

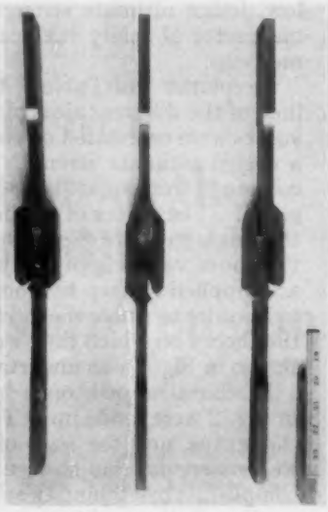


Fig. 8—Fracture of Specimens *N*, *P* and *Q*. 3/8-In. Welds 1/2-In. Plate

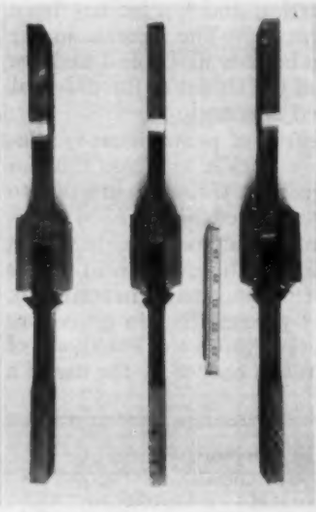


Fig. 9.—Fracture of Specimens *R*, *S* and *T*. 1/2-In. Welds 3/4-In. Plate

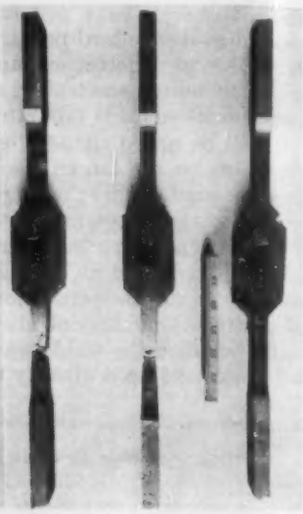


Fig. 10—Fracture of Specimens *U*, *V* and *W*. 5/8-In. Welds 3/4-In. Plate

hand welds are almost perpendicular to the direction of loading. At first glance this might seem to indicate that fracture did not occur through the throat of the weld in accordance with the theory. What actually happened, however, was this: the two welds on the left-hand strap failed first through the throat, and then the conditions of equilibrium of the remaining two welds were not fulfilled and the failure of the lower left-hand weld was by progressive tearing. This same condition will be noted in Figs. 12 and 13. It is shown in this experiment, and is common experience, that the failure of a fillet weld in tension is, when the weld is in equilibrium, through the throat.

The results of these tests are tabulated in Table 3.

The averages for the tests are given in the lower part of the table. The values in the last column are obtained by raising the values given in Table 1 in the ratio of 60,000 to 36,000; that is, they are the values for the ultimate strength per linear inch calculated by the theory shown in Fig. 1, using an ultimate tensile strength of weld metal of 60,000 lb. per sq. in. The agreement between the calculated values and the observed values is remarkable.

The results are plotted in Fig. 14. With the exception of the point for the 3/4-in. weld, the agreement between the two curves is about as good as can be expected.

The writer has no satisfactory explanation to offer for the greater strength of this size. The welds were checked and the throat areas found to be correct; the fractures were very clean and were those of very good weld metal. It is possible that the welder made a better weld on this one plate than he did on any other.

It has been contended that the double-strapped type of joint should not be used for the determination of the values of fillet welds in tension. In order to determine this point, other experiments were conducted in which a double-T joint was used instead of a double-strapped joint. In the former type no friction is possible because there are no bearing surfaces. The results obtained from the two different types of specimens disagreed less than did the results of the specimens of the same type. In other words, it appears that friction has little influence on the strength of fillet welds in tension.

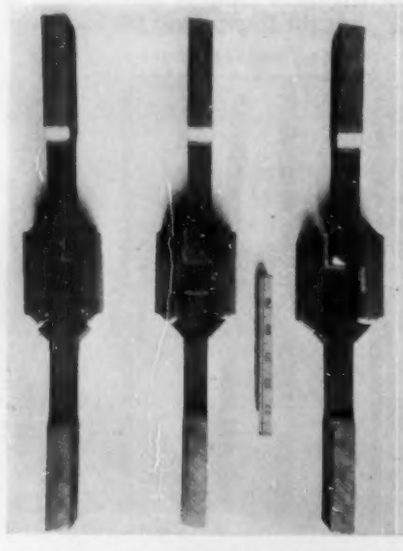


Fig. 11—Fracture of Specimens *X*, *Y* and *Z*. 5/8-In. Welds 1-In. Plate

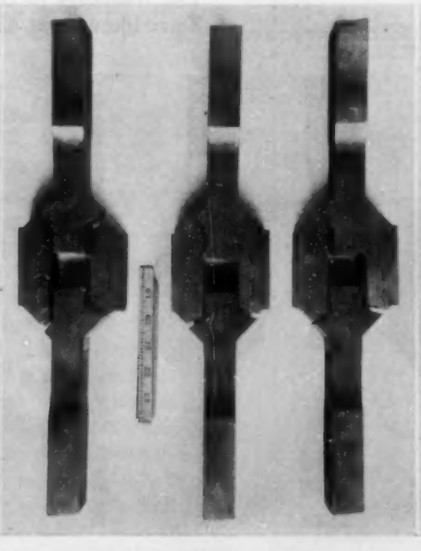


Fig. 12—Fracture of Specimens *AA*, *BB* and *CC*. 1-In. Welds 1 1/4-In. Plate

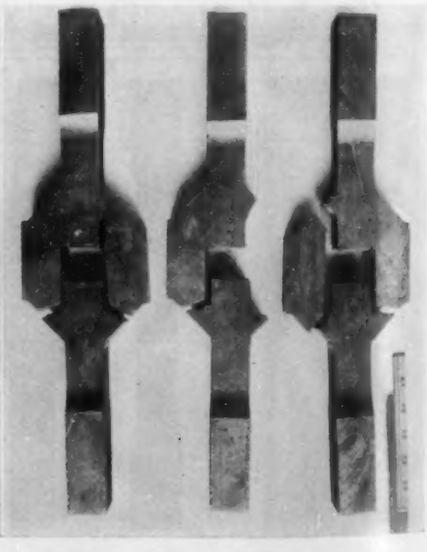


Fig. 13—Fracture of Specimens *DD*, *EE* and *FF*. 1 1/4-In. Welds 1 1/2-In. Plate

Referring again to Fig. 1, the lines of stress shown in this figure are diagrammatic only, and show how the stresses are assumed to act. Recent experiments conducted by the writer show that at low loads there are concentrations of stress at the root of the weld. As the loads increase the stress across the transverse leg of the weld becomes more uniform until at the time the weld is developing its rated strength the distribution of stress is almost that shown in Fig. 1.

The writer submits that the agreement between the values for fillet welds calculated as shown in Fig. 1 and those obtained from actual test is sufficient evidence to justify the calculation of fillet welds on that basis. Furthermore, even if the agreement were not as close as that shown, the simplicity of the method would be sufficient reason for its use.

SPECIMEN NUMBER	SIZE OF WELD "T" (INCHES)	LENGTH OF WELD (INCHES)	THROAT AREA OF TWO WELDS (SQ. IN.)	BREAKING LOAD (POUNDS)	ULTIMATE STRESS NORMAL TO THROAT OF WELD (LB. PER SQ. IN.)	ULTIMATE STRENGTH OF WELDS (POUNDS PER LIN. INCH)	THEORETICAL ULTIMATE VALUE PER LINEAR IN. AT 60,000 LBS. PER SQ. IN.
19-D	1/8	1.501	.3185	11,640	51,680	3,880	
19-E		1.503	.3189	15,700	69,620	5,220	
19-F		1.503	.3189	14,560	64,570	4,840	
19-G	3/16	1.503	.4782	27,650	82,360	8,260	
19-H		1.504	.4786	18,460	54,550	6,140	
19-J		1.504	.4786	9,400	27,780	3,120	
19-K	1/4	1.504	.6383	23,500	52,070	7,810	
19-L		1.504	.6383	25,940	57,470	8,620	
19-M		1.504	.6383	20,540	45,510	6,830	
19-N	3/8	1.501	.9288	34,480	52,500	11,480	
19-P		1.502	.9294	41,360	62,540	13,770	
19-Q		1.504	.9307	37,740	57,350	12,550	
19-R	1/2	1.505	1.1971	48,260	57,010	16,030	
19-S		1.505	1.1971	52,410	61,910	17,410	
19-T		1.504	1.1963	53,660	63,430	17,840	
19-U	5/8	1.503	1.4612	61,050	59,090	20,310	
19-V		1.501	1.4593	60,680	58,800	20,210	
19-W		1.503	1.4612	59,450	57,540	19,760	
19-X	3/4	1.465	1.6833	88,280	74,170	30,130	
19-Y		1.500	1.7235	86,770	71,200	28,920	
19-Z		1.504	1.7281	82,710	67,690	27,500	
19-AA	1	1.500	2.2539	91,500	57,410	30,500	
19-BB		1.497	2.2494	97,000	60,380	32,400	
19-CC		1.498	2.2509	99,100	62,260	33,080	
19-DD	1 1/4	1.495	2.7750	127,300	64,880	42,580	
19-EE		1.488	2.7620	122,250	62,600	41,080	
19-FF		1.502	2.7880	121,200	61,480	40,350	
AVERAGE VALUES							
19-D-E-F	1/8	1.503	.3188	13,970	61,960	4,650	4,500
19-G-H-J	3/16	1.504	.4785	18,570	54,300	6,170	6,750
19-K-L-M	1/4	1.504	.6383	23,330	51,680	7,750	9,000
19-N-P-Q	3/8	1.502	.8256	37,860	57,600	12,600	13,130
19-R-S-T	1/2	1.505	1.1968	51,440	60,780	17,090	16,870
19-U-V-W	5/8	1.502	1.4606	60,390	58,480	20,100	20,620
19-X-Y-Z	3/4	1.490	1.7116	85,920	71,020	28,850	24,370
19-AA-BB-CC	1	1.498	2.2514	95,870	60,220	31,990	31,880
19-DD-EE-FF	1 1/4	1.495	2.7750	123,580	62,990	41,330	39,380

Table 3—Results of Tests

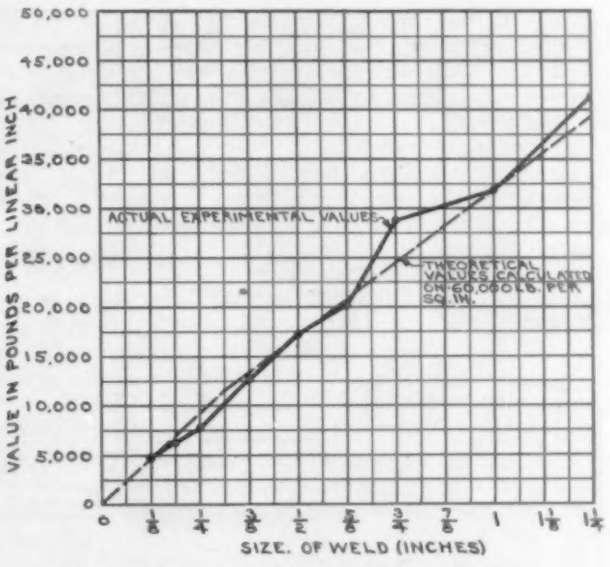


Fig. 14—Relation between Observed and Calculated Values for the Strength of Fillet Welds in Tension

The Welding of Wrought Iron

By JAMES ASTON

†This paper was presented during the Annual Meeting of the American Welding Society, April 27th to 29th, New York, N. Y., by James Aston, of A. M. Byers & Co.

THE technique and results in welding wrought iron in the major aspects parallel those for steel but in certain important features there are special considerations which must be taken into account. That there are some differences is evidence that special characteristics of chemical or physical constitution are playing a rôle and, consequently, no discussion of the welding of wrought iron would be complete without first bringing about an appreciation of the characteristics which differentiate it from the other types of ferrous materials.

The origin of wrought iron may be taken as coincident with the earliest record of ferrous products. Authentic samples from Egypt and India date from several thousand years before Christ. Manufacture was on a fairly well established plane in Egypt, India and medieval Europe a thousand or more years before the Christian era. Iron instruments, tools and weapons were used in Greece in 1400 B. C., and in Assyria and Italy in 1100 B. C. History records their use in Central and Western Europe in 1000 B. C. and in Styria and Carinthia before the Christian era. The noted "Pillar of Delhi" is generally assumed to date from 400 A. D. The use of iron was general in Europe in the Roman Empire and heat treatment of tools and weapons was then practiced.

Early manufacture progressed through centuries of primitive production in the hearth and forge and the limitations of these methods resulted in a material conforming in all essential characteristics to the product which we now chiefly classify as wrought iron. Almost to the end of the eighteenth century production was by direct reduction of the ore to a malleable product in a single operation, in sharp contrast to present-day procedure in the steel as well as in the wrought iron industry.

An epoch in the iron industry dates from Cort's invention in England in 1784 of the puddling process. In conjunction with the previously developed blast furnace, it made possible greater flexibility of operation, latitude in selection of raw materials, control of product, expansion of output, and centralization of manufacture, meeting, thereby, the growing needs of advancing civilization. The product produced by an indirect refining of the pig iron was wrought iron conforming in all essentials to that of the more primitive eras.

The puddling process was the bulwark of the iron industry and, for about seventy-five years following its inception, was by all odds the dominant means by which the world secured its needs of a forgeable, workable ferrous product.

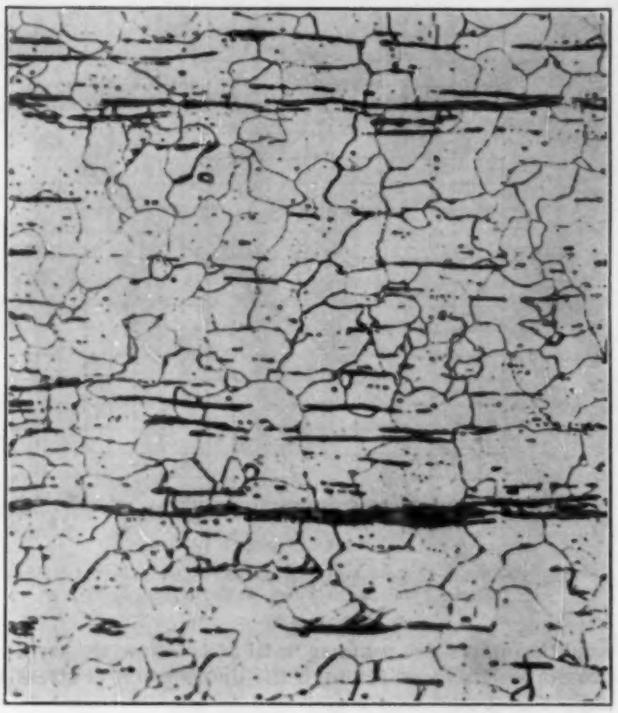


Fig. 1— × 100. Wrought Iron Plate Longitudinal

In 1855, there came the birth of the revolutionary Bessemer Process and, in conjunction with the equally prominent Open Hearth Process which shortly followed, the world entered the "Age of Steel" which has played such an outstanding rôle in our contemporary development and civilization. In the United States, it made possible an expansion in the use of iron from 55 lb. per capita in 1850 to upwards of 1000 lb. in 1929.

A summary of this historical outline discloses the interesting fact that wrought iron has had a conspicuous place in world development for several thousand years. Steel, as we now know it, is a comparative infant with a "place in the sun" of only 75 years. In this brief period it has, by reason of its large tonnage and low cost possibilities, inevitably grown to its present dominant position in the industry.

With the departure in methods which were significant of the steel-making processes, there came a departure in characteristics of product, as contrasted with the wrought iron of the preceding era. This significance was not noted in the earlier days to the extent that we now recognize, due, in considerable part, to a lack of technical knowledge and facilities for intimate research. Today, the metallurgist is fully cognizant of the fundamental differences between wrought iron and steel. And yet, it is not exaggeration to state that among consumers there is a decided misconception of the essential characteristics which give to wrought iron those qualities which have enabled it to fit into special fields of utility.

While the same basic materials and reactions enter into the production of wrought iron and steel, the marked points of difference in the two products are primarily the result of end temperatures and conditions prevailing in the processes of manufacture. Both refine the metal charge; both produce a slag in this refining. In steel-making, the slag resulting from the refining operations separates out because the final temperature of the heat is above the fusion point of the metal and of the slag. In wrought iron production, on the contrary, the final temperature is lower than that required to fuse the metal. It solidifies, therefore, to a pasty mass in the bath of slag and is disintegrated therein by manual or physical influences. In confirmation of this distinction, the following definition of the American Society for Testing Materials may be quoted:

"Wrought iron is a ferrous material, aggregated from a solidifying mass of pasty particles of highly refined metallic iron, with which, without subsequent fusion, is incorporated a minutely and uniformly distributed quantity of slag."

Wrought iron exhibits a distinctly fibrous fracture, while steel is decidedly crystalline. Chemically, wrought iron is found to have a highly refined base metal, free from segregation of metalloids, while steel is usually less free from carbon and associated metalloids. Under the microscope, the refined base metal in wrought iron is shown to be intermingled with particles, or threads, of iron silicate slag, while steel is free from this ingredient.

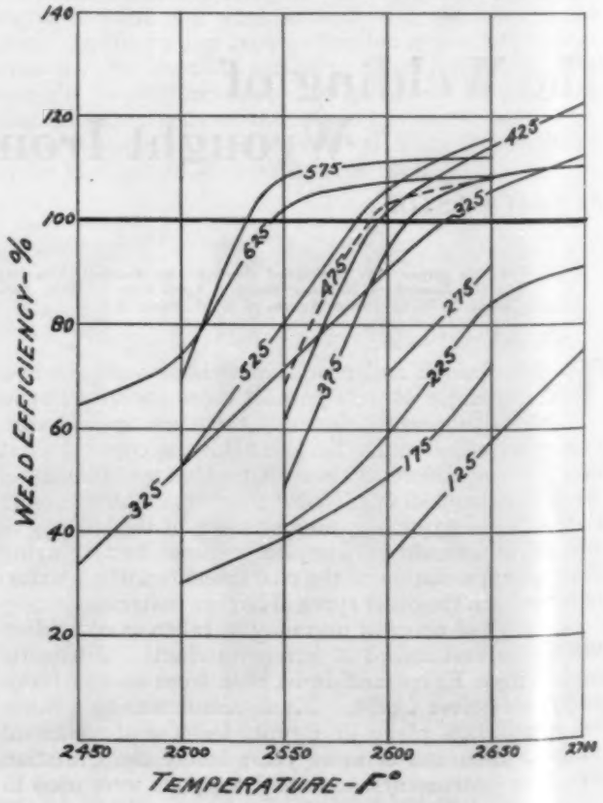
Difference in properties of the two classes of materials is dominantly related to this feature.

A typical chemical analysis of wrought iron is as follows:

Carbon	0.03%
Silicon	0.14
Sulphur	0.02
Phosphorus	0.13
Manganese	0.03

In commenting upon this analysis it must be borne in mind that wrought iron is a composite material and that practically all of the silicon and manganese, and a considerable part of the phosphorus, are oxidized constituents associated with the slag. The resultant

FIG 2
RELATION OF WELDING EFFICIENCY TO TEMPERATURE AND PRESSURE



low metalloid content of the base metal is significant of a high order of purity.

A typical microstructure of wrought iron is given in Fig. 1 magnified 100 diameters. The high purity of base metal is apparent. Incorporated therein is the slag with a thread-like distribution brought about by the directional effects of rolling. The character of slag distribution is influenced by the amount of work in rolling but in all well-made wrought iron it is of a microscopic order of magnitude and there will be several hundred thousand slag filaments per square inch of section of the metal.

In contrast with the microstructure of wrought iron, steel will show the same general grain structure interspersed with pearlitic areas in amount increasing in proportion to the carbon content. Also, and of paramount importance, no material of the steel class, even though it is in the realm of the so-called "commercially pure irons," will exhibit any of the slag association so characteristic of and fundamental to the structure of wrought iron.

Wrought iron has physical properties which are a reflection of its base purity and slag incorporation. Typically, the ultimate strength is about 48,000 to 50,000 lb. per square inch, yield point 30,000, and the elongation is from 18 to 30 per cent in 8 in., varying with the rolling history and the type of commodity produced. The important feature to be borne in mind is that the slag filaments give the material directional properties, which result in a lowered transverse strength and ductility as contrasted with the customarily cited longitudinal properties. In plate, or like commodities, the directional differences may be equalized, if desired, by cross rolling.

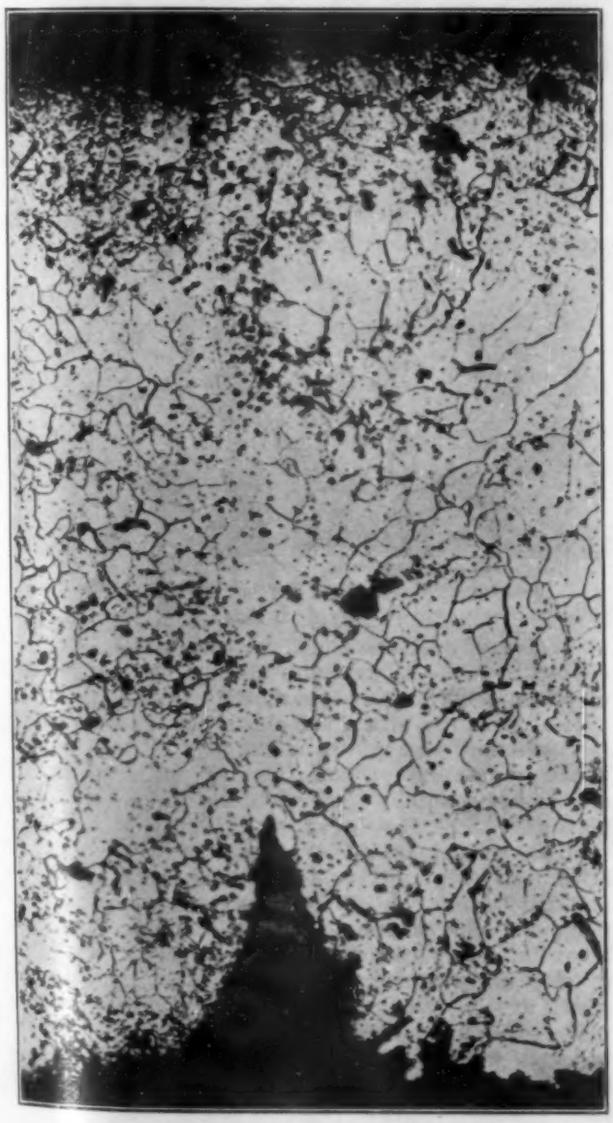


Fig. 3— × 100. Plastic Weld Butt Weld Pipe

Outstanding characteristics of wrought iron, which are the basis of its employment, are welding and threading quality, resistance to shock and vibration, and resistance to usual corrosion influences. While opinions may differ on some of the features just enumerated, nevertheless there exists a substantial market for the material among experienced users.

Limitation of manufacture, as exemplified by the puddling process, together with relatively high production costs, have narrowed the use of wrought iron to special services where its merit is recognized. However, the past few years have seen iron put upon a plane of manufacture closely paralleling that of steel in tonnage and cost possibilities. Expansion of markets should result, and the product is already available, or in the course of exploitation, in the form of plate, sheets, wire, bars and forging stock, in addition to pipe; the last named having been the important outlet in recent years. Alloy wrought iron with improved physical properties is an accompanying development.

In view of the above, it is all the more appropriate that attention should be given to the welding characteristics of wrought iron. Superior welding quality has been a recognized feature from earliest history. It is common knowledge that for a long time after steel was thoroughly established in engineering uses the blacksmith preferred wrought iron where welding was a factor. It was only by careful development of the quality of steel for welding, coupled with an educational program, that today's generally satisfactory results were attained.

Two types of welding may be considered—plastic and fusion. The several factors affecting strength and efficiency of weld are, in general, common to both types, but certain of the factors are of greater emphasis in accordance with the method employed.

In plastic welding the chemical composition and physical characteristics of the metal are of primary importance. Temperature and pressure during welding are of vital significance. It is generally recognized that all of the metalloids usually associated with standard grades of steel are harmful, rather than beneficial in their influence upon the ease and efficiency of welding. Carbon above the 0.10 per cent customary in welded pipe grades of steel is not desirable for the rapid type of seam welding which is characteristic of that operation. Silicon in the base metal is especially detrimental while increase in phosphorus, manganese and sulphur content tends to poorer welding. Of the unusual constituents, copper in moderate amount, and chromium in very small quantities, interfere with welding. Where segregation of the constituents occurs, as is not uncommon in steel-making, the resultant local increases above the normal amount indicated by an average analysis, aggravates conditions and is liable to result in spotty welding along the seam. In line with these observations, therefore, it is evident that the best welding quality is attained with high purity of base metal as reflected by practical elimination of metalloid content. Also, in pipe welding, it appears that steel which has been refined to the extent of some oxidation gives superior results.

Well-made wrought iron possesses the desirable attributes of very low metalloid content and absence of segregation of constituents. In addition, it is well recognized that the inclusion of iron-silicate slag has a marked physical action in protecting the metal during heating and fluxing the oxides so that better surfaces are presented for the plastic union of iron to iron.

Extended research on wrought iron has confirmed the observations regarding the metalloid effects. In addition, it has disclosed that the composition of the slag has a marked influence upon the welding quality in pipe manufacture. In view of the fact that the newer developments in wrought iron production, mentioned previously, enable intimate control of both slag and metal characteristics, it is not surprising that welds of uniformly high strength are being obtained in the pipe mill.

The curves of Fig. 2 show in a striking manner the influence of temperature and pressure in welding. The data clearly show that there are critical limits of temperature and pressure below which good welding will not result. While a pseudo weld, commonly called "pasted," will result at relatively low temperatures and pressures it was necessary, in order to reach the strength efficiency of 100 per cent, that a pressure of 550 lb. per square inch be employed with a temperature of 2550° F. whereas, at a temperature of 2700° F., a pressure of 275 lb. sufficed. High strength welds were not obtained with temperatures of 2450° and 2500° F., even at the high pressure of 625 lb. per square inch. Proper heating is an essential to effective welding. Higher temperatures are necessary in butt welding, where moderate pressures only are applicable, than are needed in lap welding of pipe where high pressures are possible.

While the data shown apply to wrought iron, the fundamental principles noted are applicable to the entire problem of plastic welding of wrought iron and steel. Naturally, variations of metal composition and other characteristics will modify the critical limits for the different types of material. The general favor in which forge-welding has been held is not a fantasy, since coupled with proper heating the pressure of the blow is an effective aid to weld strength. A secondary, but by no means unimportant, adjunct to this type of welding is the improvement of the metal as a result of the work of forging in reducing the coarse grain structure which accompanies the high heats of welding.

Electric resistance, spot and flash welding fall into the general classification of plastic welding. The results obtained with wrought iron are excellent and the inherent characteristics of the metal are preserved. Experience indicates that somewhat higher temperatures are desirable, obtained by using higher current densities than those generally prevailing for soft steel. There are no ill effects from this practice since wrought iron will withstand the high temperature. The slag inclusions serve to protect the base metal from oxidation at the high heats and it will not undergo coarsening of grain structure to the extent that one experiences this effect in steel.

Electric resistance welding of longitudinal seams is becoming an important factor in the manufacture of pipe, particularly in the butt welding of smaller sizes and in substitution for standard lapwelding operations in the larger sizes.

In summation, a plastic weld may, under proper conditions, attain a strength equal to that of the body metal. A proper adjustment of temperature and pressure is essential to the extent that each must exceed a lower critical limit which varies with the characteristics of the material being welded. Plastic coherence is a necessity and the field of satisfactory materials is quite circumscribed in this respect, and particularly so under the conditions of rapid welding prevailing in pipe manufacture. As an instance in point, high carbon and alloy steel pipe are being made by seamless methods, primarily because seam welding of the usual type cannot be satisfactorily accomplished. Aside from the direct effect of pressure, hammering of the weld has a most beneficial effect in breaking down the coarsened grain which results from the high temperature. While a well-made butt weld may have an efficiency of 100 per cent, the lap seam is the more generally reliable and consistent because of greater contact area in the weld and more positive application of pressure during the operation. Figure 3 shows the typical structure of a good plastic butt weld resulting from standard pipe mill practice.

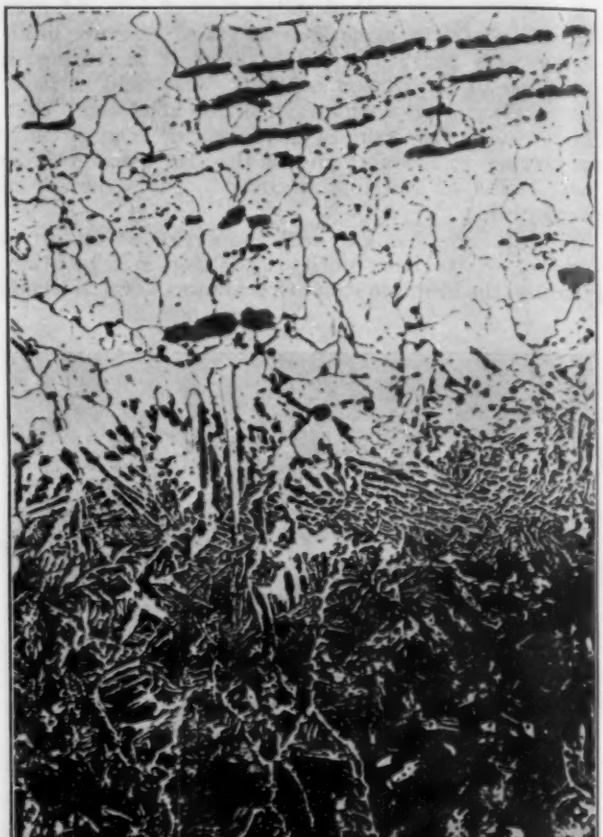


Fig. 4— × 100. Acetylene Torch Weld High-Test Rod

The reputation of wrought iron for high welding quality has naturally been established upon the basis of plastic welding. In favor of this type of operation, from the wrought iron viewpoint, must be conceded the advantage of preserving to the maximum degree the inherent association of metal and slag which is the dominant characteristic of the material. However, all of the factors which are of value in plastic welding are of merit in the fusion process. Consequently, it may be stated as fact that fusion welds of wrought iron may be made with entire satisfaction by any of the customary methods with only such caution or experience as is necessary with any change of metal types, or to take care of fundamental differences in characteristics.

It is in line with experience to state that fusion welding

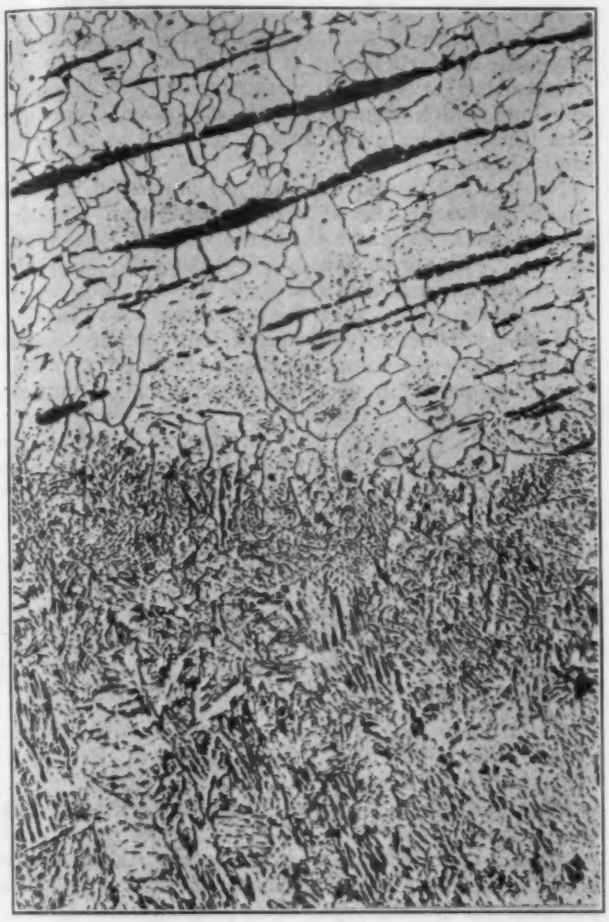


Fig. 5— × 100. Carbon Arc Weld

is applicable to a much wider range of materials and compositions than plastic welding. By reason of this, a union of dissimilar materials may be made, a filler metal may be used which is unlike that of the materials to be joined, and alloy steels may be united which are non-weldable from the viewpoint of plastic coherence.

With the inherent flexibility of the fusion welding operation, there are several factors which, individually or collectively, determine the strength of the weld:

First.—The filler metal may, by modifications of carbon or alloy content, have properties varying from the relatively low strength and high ductility of soft iron to the higher strength and brittleness conferred by the additions.

Second.—The alloying relationship which may form at the fused junction of the base structure and the filler metal may conceivably have a marked influence upon the final result. For example, if there is no alloying, the junction is a "paster;" if a brittle compound forms, this zone is devoid of ductility.

Third.—Oxidation products may not be cleared from the fused metal and may remain therein as inclusions or even as a layer in the fusion zone; obviously there may be weakening of the weld strength in the former case and practical non-welding in the latter.

Fourth.—High temperatures needed in welding may cause a coarsening of grain and weakening of the body metal back of the weld section.

Fifth.—A heavy body section may exert a chilling effect upon the filler metal in the weld zone and cause hardness and embrittlement, this effect, of course, being most liable where carbon or alloy weld rods are employed.

In the application of these fundamental thoughts to the fusion welding of wrought iron, the following suggestions may be advanced. The material, as noted heretofore, has welding characteristics of a high order by reason of high base purity and the ferrous silicate slag association. The latter is a valuable aid in protecting the metal surface and in its self-fluxing action; influences of the type sought in coated welding rods. But it must be borne in mind that the first fusion in wrought iron is that of the included slag at a temperature below that of the base metal and too low for the application of the weld metal. Temperatures should be raised somewhat above those of the first greasy or fluxing appearance.

Experienced welders have no difficulty in judging the proper temperature but an inexperienced one, judging only by the first appearance of a fused or fluxed surface, will usually apply metal before fusion of the base metal has been attained, resulting in low strength welds. It should be remembered that wrought iron can withstand higher heat without damage than other ferrous metals and, in general, should be worked hotter for best results.

A puddle of molten metal should always be maintained at the point where the rod is being applied, the end of the rod being kept immersed in this molten puddle until enough metal has been deposited. Then the edges of the molten puddle and the surrounding colder metal should be fused together to obtain a solid union. The weld progresses by repetition of this procedure, care being taken to add no metal from the welding rod except through the vehicle of the molten puddle. In order to

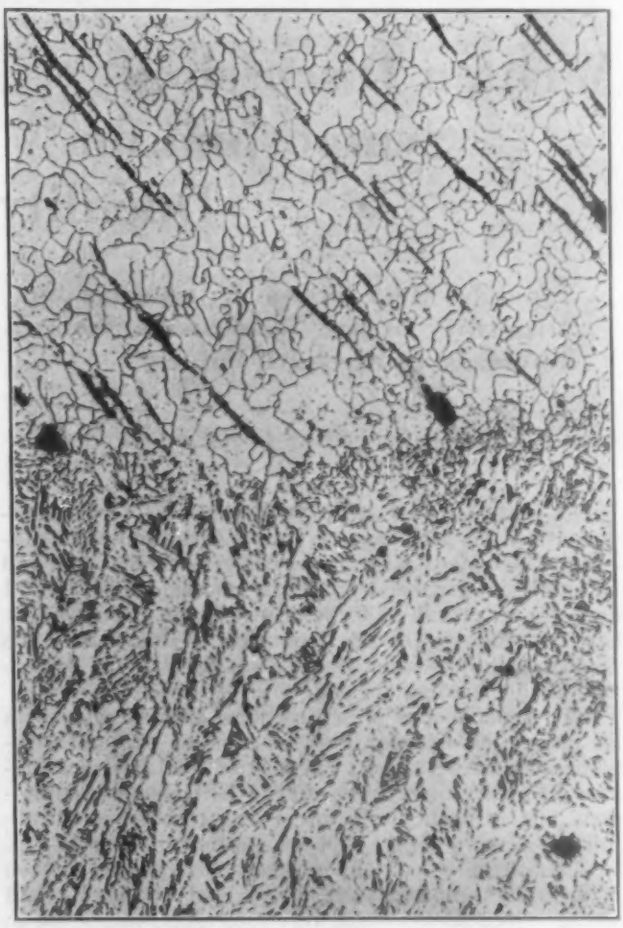


Fig. 6— × 100. Electric Arc Weld Metal Electrode

obtain sound weld metal free from oxide, which produces low strength and porosity, the molten puddle should be disturbed as little as possible. Excessive rubbing or agitating of the molten pool should be avoided as this causes undue exposure of the molten metal to the atmosphere, resulting in the formation of oxide which may become trapped in the weld.

With reasonable care during the welding operation, impurities can easily be floated to the surface, aided by the fluxing effect of the wrought iron slag. Undue agitation of the puddle may also result in molten metal being spread out over unfused surfaces, causing laps or other defects in the weld.

The quality of welding rod is of importance with the same factors governing the selection as prevail for steel and with numerous types to choose from. In general, however, low carbon iron rods are preferable for most wrought iron welding.

As noted previously for resistance welding, in the electric welding of wrought iron by arc methods, experience indicates that higher heats and, therefore, higher current densities are advisable as compared with similar practices with steel. While no definite proportion can be set for the wrought iron, due to variations of conditions and, in part, to a dearth of authoritative data, indications are that about 10 per cent increase over the values used for soft steel is a fair approximation.

Figures 4, 5 and 6 are microstructures of fusion welds of wrought iron plate and are self-explanatory. In all cases, the intimate nature of the junction of the wrought iron and the weld metal is shown, and the absence of anything which would indicate a "pasted" condition. The type of filler metal used is reflected in the several photographs.

No doubt the above outline of suggested practices which has been gathered from the experience of welders, has a familiar ring to men who are making the work a specialty. It serves only to emphasize the fact that in the major features the welding of wrought iron necessitates no deviation from the technique established for soft steel. Inherently, wrought iron possesses in the highest degree the composition and characteristics which are fundamental to good welding by either plastic or fusion methods. As a material having some special characteristics, notably that of slag association, there are some details of practice which must be observed or modified, but none are of a type which require extended training for mastery, or which will upset the established order of technique or appliances.

That wrought iron is a material of excellent welding character is established by its historical record; that it fits in with contemporary methods is attested by the numerous applications of welding to pipe lines and other fabrication jobs without difficulties in practice and with an unbroken record of successful accomplishment.

Written Discussion: Symposium on Ductility

Paper by Mr. Charles H. Jennings on "Ductility in Arc Welds with Some Reference to Strength Values."

By **A. M. CANDY, Westinghouse Electric & Mfg. Co.**

IN COMPLIANCE with your request to give a discussion on Mr. Jennings' paper, I am herewith submitting my discussion in writing inasmuch as it will be impossible for me to attend the meeting this year. I am very sorry indeed to be absent because this will be the first meeting of the American Welding Society's Annual Meetings which I have missed since the formation of the Welding Society.

Mr. Jennings has presented some useful material in an interesting manner and has brought out quite emphatically the very great effect upon ductility measurements which the size and shape of the test specimen produce. It is particularly interesting to observe the results obtained with the Type 3 specimen shown by Fig. 5 wherein the elongation is determined by the stretch of the metal around the small holes drilled through the weld metal. Such results while very interesting can be made very misleading and confusing to unsophisticated persons who are not familiar with the peculiarities cited by Mr. Jennings.

While I agree with most of the writers taking part in this discussion of ductility that it is of very great importance for certain types of structures which are subjected to breathing action, vibratory loading, shock loading, or in other words any type of load which will impose a large number of stress alternations or stress reversals during the life of the structure, nevertheless there are some types of structures in which the highly ductile welded connection is not so essential. Structures falling in the latter classification are, for example, bedplates for most machinery, and buildings. The fact that many thousands of tons of such construction have been built and used during the past 6 to 10 years and in some cases even longer without any major failures proves that with proper design, welded connections even though of relatively low ductility can be depended upon to serve their purpose. While it is entirely possible to produce welded connections which will show 32 to 36% elongation by the free bend test and 26 to 14% elongation in 1 inch by tensile test, nevertheless I wish to sound a word of warning to designers in placing too much dependence upon such high ductility characteristics to protect them in their design work. The reason I am sounding this note of warning is because I have seen welding work carried out where high localized cooling stresses were produced in very rigid members welded together with welding wire which will show ductility values of the order just mentioned. Upon cooling the welds have fractured. To prevent this from happening it was necessary to cut out the weld metal and re-weld, putting the metal down in layers and peening very carefully as the work progressed in order to stretch the metal to prevent such fractures. In spite of this I still believe that the use of the highly ductile metal is of a very decided advantage in these cases because the likelihood of such failure surely must be much less than it would be if weld metal of low ductility is used for these applications.

My chief point is, therefore, to warn designers and fabricators against carelessness in design and fabrication resulting from placing too much reliance and against a sense of false security and against throwing discretion to the wind simply because their welded work is to be done with electrodes producing highly ductile metal.

Comments on Paper by E. R. Fish on "Why Ductility of Welds Is Important in Welded Pressure Vessels."

By H. E. ROCKEFELLER, The Linde Air Products Co.

THE comments which I have to make will be confined to Mr. E. R. Fish's presentation on ductility as applied to welded pressure vessel construction. Mr. Fish, I know, has given a great deal of consideration to the question of ductility in welded pressure vessel construction, and as Chairman of the Unfired Pressure Vessel Section of the A. S. M. E. Boiler Code Committee and as Chief Engineer of the Boiler Division of the Hartford Steam Boiler Inspection and Insurance Company, has been largely responsible for the introduction of minimum ductility requirements in welded pressure vessels, both in the A. S. M. E. Unfired Pressure Vessel Code and in the acceptance of welded products for insurance. In view of these capacities, however, and probably logically so Mr. Fish has leaned toward the establishment of as high ductility requirements as could be commercially obtained. In other words, Mr. Fish has fostered a weld ductility "as high as the traffic will bear." The basis for this attitude, I assume, may be said to be threefold.

In the first place, it has been contended that the higher the ductility, the safer will be the construction in service. In the second place, it has been contended that the higher the ductility, the less is the likelihood for imperfections in the weld metal, such as laps, lack of fusion, penetration, blowholes, etc. As a third reason, it has been contended that the higher the ductility, the less is the likelihood for cracks developing during fabrication.

In considering the necessity for high ductility for welded pressure vessels in service, many have been prone to attribute to high ductility, high resistance to shock and fatigue. It is my feeling that this growing trend should be discouraged, since from a good many aspects it may be entirely erroneous. In so far as shock is concerned, it has been demonstrated that steel may have a very high ductility and at the same time, if notched, a comparatively low shock resistance. This has been very vividly indicated on tests made at low temperatures. In the matter of fatigue, furthermore, it has been further indicated that since fatigue resistance is, in general, associated with the yield point or ultimate strength of steels, and since increasing yield points are generally associated with decreasing ductility, for the same operating fiber stress a material having a high yield point and comparatively low ductility may be much more resistant to fatigue than one having a very high ductility and low yield point. For high temperature service, furthermore, it is becoming more and more recognized that the relatively high ductility and low yield point steels are not nearly as satisfactory as other steels with higher yield points and lower ductility.

It has, of course, often been stated that high ductility affords an additional factor of safety in welds containing imperfections, such as small laps, etc., by preventing sudden extension of these laps into cracks and failure of the weld in service. This point, however, should not, I believe, be directly associated with ductility but with the matter of weld imperfections themselves. As a matter of fact, it is my feeling that the attempt to tie these two separate factors together has been the cause of some general misunderstandings regarding the necessary requirements of ductility. I am firmly convinced that freedom from imperfections in welds is highly desirable and for certain services is essential. I am also convinced that where freedom from weld imperfections is assured, there is no need for ductility in the weld of the magnitude at present prescribed for Class 1 welding in the A. S. M. E. Unfired Pressure Vessel Code. Since, furthermore, tests have been incorporated in this code which definitely require the investigation and reasonable assurance of freedom from imperfections in welds made under the Code, I for one can see no reason for tying in ductility requirements with the matter of weld imperfections.

With respect to the necessity of ductility in the weld and base metal to take care of stresses imposed during the fabrication, there is no question but that a certain amount of ductility is required to compensate for such stresses. However, there is also a definite need for knowing how to do any job in such a manner that excessive stresses are not set up.

Mr. Fish has referred to the extreme difficulty of welding cast iron and its peculiar susceptibility to cracking during or after the welding process. This is an excellent example of knowing or not knowing how to do a job. All of us who have had any extensive experience in the welding of cast iron know that, if proper precautions are taken, it is one of the easiest of all metals to weld by the oxyacetylene process. That there have been some failures in the attempt to repair cast iron castings can be attributed definitely to the fact that where such failures occurred the welder did not know how to take care of the contraction and expansion stresses or, in other words, did not know how to do the job.

In the development of the welding of thick wall pressure vessels, some fabricators have, as Mr. Fish has stated, run into the problem of overcoming cracking due to fabricating stresses. These troubles have been overcome, however, I am sure almost without exception not by increasing the ductility of the weld metal, but by changing the technique of fabrication to eliminate the cause of the trouble.

In summing up, as I have stated before, it is probably the natural objective of people who are sitting in a regulatory capacity such as Mr. Fish, to suggest requirements which can be practically met and which at the same time tend to increase the factor of safety on construction. It is the duty of manufacturers and users, however, to bring to the attention of regulatory bodies any accredited data which prove that existing specifications are either unnecessarily restrictive or, on the other hand, are not conducive to obtaining the desired results for the service or services intended. I have attempted to indicate that, as is my opinion, high ductility requirements (of the magnitude of 30% or more) for welded pressure vessel construction are not only unnecessary, but may work to the disadvantage of securing the most satisfactory results for certain pressure vessel services at the present time included under the scope of both the A. S. M. E. and insurance company requirements.

It is unfortunate that to date the data on the subject of ductility have been mainly matters of opinion and experience, and I am heartily in accord, therefore, with Mr. Fish that the manufacturers and users of welded pres-

sure vessels should develop as soon as practicable, sufficient data to confirm opinions and experience, and to establish a more accurate understanding of the requirements and limitations of weld ductility as a factor in the determination of the reliability of welded construction.

Discussion of E. R. Fish's Paper Entitled "Why Ductility of Welds Is Important in Welded Pressure Vessels."

By A. D. RISTEEN

I SHOULD like to make one or two short remarks in connection with Mr. E. R. Fish's paper on "Ductility of Welds" in welded pressure vessels. Mr. Fish states that such vessels have not been acceptable for insurance, and that they have quite consistently been refused coverage. Of course, this is true up to a certain point, because anybody can buy himself a welding outfit and try his hand at welding, whether he is competent to produce a good weld or not. The insurance company with which I am personally connected, however, will accept welded pressure vessels for insurance, provided certain conditions are fulfilled. The workman must be competent, the apparatus that he uses must be standard, the filling material (as well as the material of which the pressure vessel is constructed) must be satisfactory, and (finally) if the pressure that is to be carried is great enough to throw serious stresses upon the vessel that is to resist the pressure, then the welding must be done in strict accordance with a procedure that has received the approval of welding experts of the highest order. If these conditions are fulfilled, I see no reason why pressure vessels should not be considered insurable, provided that they are designed correctly and with due regard to the pressure that is to be carried. I am speaking of unfired pressure vessels. I have not been in immediate touch with the welding industry for some little time, and hence I do not wish to express any opinion, at present, with regard to the insurability of welded pressure vessels that are exposed to external heat.

I should like to emphasize, once more, the importance of having the work done by a competent welder and in accordance with an approved method of procedure. I remember an occasion, back in the early days of fusion welding, when I had a small and not very important job of welding done at a wayside shop, in a small town, on my automobile. As I learned afterward, the job called for very slow cooling, and the workman kept me waiting for well over an hour, when I wanted to be on my way. Feeling that the wait was needlessly prolonged, I protested, and I shall never forget the quiet answer that came back. "*You* have nothing to lose," said the workman, "but an automobile; while I have a *reputation* at stake." I am sorry I do not remember who that man was, nor where he lived; but I am sure that he has since made his mark in the welding industry, and I would have the utmost confidence in anything he might undertake.

In conclusion, let me say that it seems to me that the extensibility that Mr. Fish suggests (namely, 20 to 30 per cent in eight inches) is needlessly large for many purposes.

Paper by H. F. Moore on "Ductility: What Is Its Significance and How Test for It?"

By W. B. MILLER, Union Carbide & Carbon Research Labs.

WE WERE somewhat disappointed that Professor Moore did not suggest some numerical rating for ductility. We do recall that at a meeting held in this building on February 18th he made the statement that any welded structure that distorted 5% would be considered a failure. Ductility enough to take care of this amount of distortion without cracking would seem necessary, but how much more is needed to take care of overloads is not known.

However, Professor Moore's paper is very important in that it points out the place which ductility holds among the other physical properties, and particularly its relation to "crackless plasticity." This property which has been termed "crackless plasticity" embraces one of the qualities that engineers have generally ascribed to ductility (as evaluated by elongation measurements) and for which they have urged high ductility. The fact that highly ductile metals are "tender" and spreading cracks start in them easily reveals the necessity for the property of "crackless plasticity." If crackless plasticity is partially responsible for the durability of a metal, there is obviously less need for extreme ductility.

As stated by Professor Moore ordinary ductility in some amount is an insurance against fracture under occasional overloads, particularly if suddenly applied, while crackless plasticity is an insurance against the formation, under repetitive normal loads, of a spreading crack starting from a highly localized stress. Since defects in a weld are the nuclei of such cracks, would not crackless plasticity be an index of the quality, or putting it another way, is not quality an index of crackless plasticity? In M. D. Rosenthal's paper is shown the failure, under repeated blows, of a fillet-welded coupon. Cold hammering of the area where fracture occurs, while probably lowering the ductility and increasing the strength, has raised the fatigue resistance. The plate at this section had high ductility which was not available under repetitive stress, a condition suggested by Professor Moore. It is possible that the increased strength has played an important part in the increased fatigue resistance. A certain amount of ductility was necessary to allow the cold work to be carried out safely.

We believe that the discussion in Professor Moore's paper supports the view that extreme ductility is not advantageous, if it sacrifices tensile strength and crackless plasticity.

Discussion of the Symposium on Ductility of Weld Metal

By G. DOAN

†Professor Doan is with the Department of Mechanical Engineering, Lehigh University.

SENTIMENT in the question of ductility seems to range all the way from certainty that the utmost in ductility is needed to thankfulness that more is not obtained. Perhaps these diverse viewpoints can be coordinated by a little careful analysis. Stress below the elastic limit in a welded object has nothing whatever to do with ductility or plasticity. Ductility deals with behavior above the yield point only. Stresses which are below the elastic limit will produce elastic deformation (temporary) in accordance with Hooke's law. The deformations will be proportional to the stress, the pro-

portionality factor being the reciprocal of the modulus of elasticity. Since this modulus for steel changes very little with the change of condition of the steel or with change of composition, we may assume that welds, of whatever ductility, will behave much as do the parts joined, as long as the stresses are below the elastic limit. In fact, in service, where the stresses are usually below the elastic limit, ductility plays no part whatsoever, and should, therefore, not be mentioned in connection with a discussion of normal service stresses. The case of two wooden parts joined by a "rubber weld" causing a concentrated deformation in the weaker, rubber part is a fallacious analogy because the modulus of elasticity of wood and of rubber are entirely different.

Another opinion is that the weld should be "stiffer" than the parts joined. This may be accomplished by using a heavier section of weld. But stiffness would not be obtained by lowering the "ductility" of the weld, for ductility is a quality which is not concerned in normal service stresses, but only in excessive stresses such as cause deformation. Stiffness within the elastic limit thus means a heavier weld or a higher modulus.

Only when the stresses pass the yield point of the metal does flow begin, and the question of ductility enter. The amount of flow which will take place before fracture begins is designated as the "deformability" of the material. This is a general term, whereas ductility is a special term and is the amount of deformation which can be produced by drawing, as of wire through a die, or of a specimen in tension without fracture. Ductility is thus a combination of tensile strength and deformability. The metal lead is highly deformable and plastic, but is not very ductile because it breaks from lack of strength in drawing through a die, before it has elongated greatly.

The yield point, being the minimum load at which flow occurs, is a measure of *resistance to deformation* (as is also the tensile strength), whereas elongation or ductility, and reduction of area, are a measure of *deformability* or *extent of deformation.*

Whether one wishes the weld to deform *extensively* or not, once the stresses have passed the yield point, is the question. If both weld and welded parts were perfectly homogeneous and free from flaws, one might say "I do not care which deforms more, so long as neither exceeds its limit of deformability and fractures." Thus, if the yield point of the weld were the higher of the two (as is stated by several of the speakers), the adjacent parts would deform until the stress had dropped to or slightly below the yield point of the parts, as in the case of relief of shrinkage stresses on the yielding to change of alignment of the structure, that is, to the relief of *internal* stress. If an external load caused such deformation and did not diminish after deformation had occurred, it would, of course, end in fracture in the parts. But usually the parts and the weld are not perfectly homogeneous. There are far more flaws, such as laps, reentrant angles, slag layers, porosity, etc., in the weld than there are in the parts joined. The *unit stress* at the root of these flaws may be at the yield point of the weld while the unit stress outside the weld, in the parts joined, is far below the yield point. Hence higher deformability is needed in the weld than in the welded parts.

Especially during cooling the stress concentration is higher in the weld, not only due to the flaws in it, but because actual average unit stress also is higher, due to the more intense shrinkage which occurs in the weld itself as compared with the shrinkage outside the weld. Liquid metal has been "poured" into the weld and it has fastened to the edges of the weld by solidification. Solidification has progressed inward from these edges toward the center of the weld, and upon final solidification at the center of the weld, the liquid mass is solidified and occupies a smaller volume. The shrinkage stresses are concentrated principally at the center of the weld, and it is here that the stress concentration is greatest. If the weld is not plastic or deformable or ductile, these stresses, due to shrinkage of volume, will fracture it. If it is slightly deformable then it may deform, but the later addition of service stresses to internal stresses may carry it past the limit of deformability to fracture. If it is highly deformable it will not crack. It, therefore, seems clear that a high yield point *and* a high deformability are desirable in the weld.

The intensity of local stress during cooling is not as great outside the weld, as in the weld itself. There are not as many flaws outside the weld as there are inside it; and finally the metal is not as hot and therefore not as weak outside the weld as inside. For these reasons every bit of deformability possible should be present in the weld during its formation. There is no logic in comparing the ductility of the joined parts and of the weld, during this stage, for the demands on the weld itself are far greater than the demands on the parts joined.

When the welding is finished and the entire object annealed and put into service, then the stresses should always be expected to be below the elastic limit, and we are not then concerned with the property called "ductility," which comes into play only after the elastic limit is passed.

If, however, the stresses pass this limit at any point in the structure, then they will most likely do so at one of the flaws or "stress raisers" in the weld. The weld must either deform or fracture. If it fractures even in a very short crack, the effect may be to raise still further the stress concentration at that point. So that even in a fully stress-relieved weld the presence of flaws demands that the weld metal be deformable.

If annealing has not been done subsequent to completion of the weld, then the weld is already stressed up to the yield point, for during cooling the stress will drop by deformation only to this point or very slightly below. The addition of service stresses thus at once raises the weld above its yield point and again it must either deform or crack.

It must be remembered also that extensive deformation of metal causes the yield point to rise, and to rise more rapidly than the tensile strength rises, so that finally the two values almost meet. In this condition any deformation (stress above yield point) will likewise be at or above the tensile strength. The metal is brittle and breaks, just as does an over-drawn wire. So there is a limit to the deformation which even a "ductile" weld will undergo.

Summary

It does, then, seem clear that the danger of cracking during cooling will be greater in the weld than in the joined parts due to (1) greater local shrinkage in volume; (2) greater concentration of stresses by flaws in the weld; (3) weaker condition of the hotter metal. The stresses will either deform the metal or fracture it. If they deform it, the stresses will drop to the yield point. Subsequent stresses in service will again raise the stress beyond the yield point and either a continuation of deformation or a fracture will result. Annealing will practically remove residual stresses. It will restore deformability to an over-worked metal.

Stresses below the elastic limit, such as one expects to encounter in service, are not in any way related to the ductility of the material. The latter is a measure of deformability after the passing of the yield point.

Stiffening of the joint against elastic stresses in no way relates to ductility.

NOTE: Recent studies by Hensel and Larsen, and others, have shown that at least a part of the ductility now obtained in the welds made with heavily coated electrodes is due to exclusion of most of the nitrogen from combination with the weld metal. When nitrogen combines with iron it forms a chemical compound, iron nitride, which remains dissolved in the iron grains if rapidly cooled. Later, precipitation of the nitride begins and the weld becomes harder and less ductile. The phenomenon is similar to the aging of duralumin.

It seems probable also, as Dr. Rosenthal has pointed out, as well as the present writer, that oxygen may also play an important rôle in the loss of ductility in bare electrode welds, where both oxygen and nitrogen are freely admitted

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General Discussion on Ductility

By J. H. CRITCHETT

†Mr. Critchett is connected with the Union Carbide & Carbon Research Laboratories.

BECAUSE of the point of view from which I am going to discuss the series of papers to which we have just listened, it is well that I introduce myself as one having charge of research and development activities and with a background of years in the operating end of steel mills and in ferro alloy manufacturing plants. The papers have all been very instructive, dealing with the subject of ductility in welded structures. This question of ductility in weld metal has been fairly well settled in the minds of competent welding engineers for some time but recently has received a great deal of publicity due to the wider use of welding in all kinds of construction and especially because of various code activities. The writings and talks of the late S. W. Miller on this subject were the clearest and most analytical, and carried the strongest conviction, of any that I have heard. To him, I believe, goes the credit for an engineering analysis and expositions showing that, with higher elastic limit and ultimate strength in the weld than in the base metal, stresses would be absorbed in, and any adjustments made by, the base metal. Under such conditions the highest degree of ductility is not the sole measure of good weld metal. In fact the most ductile may not be the best weld metal considering all the requirements of a good welded joint. Mr. Miller laid particular stress on procedure control, that is, careful attention to all phases from the initial design and layout of the work to the final inspection and testing. As I interpret today's papers, this view is still valid. The authors whose valuable contributions are under discussion approached the question of weld ductility from as many angles as the fields of activity they represent. I shall refer only briefly to three of the papers; those by a research engineer, a plant engineer and a development engineer. The research engineer has given a very valuable exposition of the various methods of measuring ductility and has brought out the effect of shape of specimen and gage length on the test results. He also has shown excellent values for strength and ductility of properly made welds, but has properly left to the mechanical and civil engineer the problem of how much ductility may be necessary and desirable in a given structure. The plant engineer has also given us the results of a vast amount of welding study in which the variables have been accurately controlled. Again, strength and ductility values are excellent. Good welding can be done in the shop as well as in the laboratory. Fine! But note the word of warning included in this plant engineer's story.

"But we must not let this observation (that ductility is an important physical characteristic) lead us to believe that ductility is a panacea for all the evils of welded construction. It is not. Neither is strict adherence to the requirements of the Unfired Pressure Vessel Code. A vessel or structure may be fabricated of the best materials obtainable and the welds may be as near perfect as it is possible to make them and yet the structure may fail in service. Why? Because the design is such that no material or weld could stand up under the stress concentrations. The engineering is at fault either because of lack of complete knowledge of the conditions of service or improper analysis of the stresses."

In the words of those great philosophers, Amos and Andy, "Check and double check."

Finally, the development engineer reports a large amount of welded pipe construction where attention to the various elements of sound engineering has brought good results. Excellent! Incidentally, this last is the only paper of the group which assembles the evidence from theory, research and practical experience, and draws what appeals to me as a conservative and sound engineering conclusion.

Next, two papers by prominent American college professors, one by a Belgian professor, and one by an engineer who has backslid to a business man. But he is a good business man, so I think we shall have to forgive him for backsliding; anyway his point of view is quite illuminating and suggests that he has not forgotten his engineering. One of the professors tells us that ductility is of importance, but that cold bend and elongation tests are not very effective as means to insure metal which shall be resistant to starting cracks at points of localized high stress under repeated loadings. He does not seem to give much credit to any of the present methods for determining the desired quality of ductility, but has hopes of the damping method suggested by Foeffle and Von Haydelkamp. Personally I do not expect much from this method for work done on it by my associates has thus far failed to yield results that can be interpreted in any helpful way.

The other college professor is a welding engineer and a consultant of note in that field, and is moreover somewhat of an economist, a psychologist and a philosopher—judging from his dinner conversation during a recent pleasant evening. His conclusion is: "We are dealing with a complicated subject from the analytical point of view—in fact, one that cannot be met quantitatively with the knowledge at present available." Later he implies that he feels 15% elongation safe and 10% too little. While his point of view is supported in his paper only by analogy, we must weigh the source, give full value to the wealth of experience on which the judgment is based, and concede that the burden of proof is on the shoulders of him who wishes to differ with the conclusion.

The contribution from Belgium sums up a very interesting series of tests with the conclusion that the more ductile both the base and weld metal, the safer the structure. Within reason this is true but I would not desire a copper joint in a steel vessel although the copper is more ductile. Furthermore, this conclusion is based on

the necessity of the metal adjusting itself to local discontinuities; in other words, on the need for "crackless plasticity" Professor Moore is perhaps the foremost international authority on this subject and has just told us that he does not feel that cold bend and elongation tests measure this property.

And so we come to the engineer-business man. How many of you have shared my experience of paying good money to hear Will Rogers, Eddie Cantor or some other of our humorists, laughed at his quips and later come to a realization that beneath the joking is sound philosophy and a wonderful knowledge of human nature? So in this case, although obviously overdrawn, the paper is built on a solid foundation. I recommend it receive your serious consideration.

Let us sum up our consideration to this point.

The Research Engineer says we can get strength and ductility in laboratory welds.

The Plant Engineer says we can get those qualities also in factory welds; but don't let the fact that we can, blind you to the need of sound engineering in welded structures.

The Development Engineer says we have built much welded work which has been eminently satisfactory, by careful attention to procedure control, and that with such construction extreme ductility is not a requisite.

One college professor says ductility is good, but that we do not know how to test for the type of ductility really needed.

Another college professor with wide consulting experience says extreme ductility is not a requisite of sound engineering construction.

And our sole business man says there is such a thing as too great ductility.

There seems to be a remarkable consensus of opinion. The one paper that seems to differ from the consensus is presented by the chief engineer of an insurance company. In that paper ductility is stressed to such an extent as to make it seem almost the sole criterion of a good weld. At the risk of being accused of taking the directly opposite stand—that is, that ductility is not important, to which I certainly never would agree—I must disagree with the implications of that paper. After a somewhat critical review the opinion is reached that the weld metal should have physical characteristics which closely approach those of the base metal. No good engineer can disagree with such a conclusion, but from a practical point of view the only method of obtaining this is with a seamless forging, and then the problem of closing the ends remains. Considering a fabricated structure there will be discontinuity at the joint. It is general practice to make composite structures and to design each part for the duty it must perform. Because the engine block of an automobile is cast iron is no justification for making the gears of the same material. In the same way the joint of a pressure vessel should be considered from the point of view of the work it must perform, and should be designed and executed accordingly. This consideration has led me to divide the necessary properties under four classifications. In the order of importance these are—first, ability to transmit stresses; second, resistance to deterioration in service; third, ability to withstand accident and abuse; and fourth, ease of fabrication. Going further with the analysis and mentioning only the most important of the properties, under the first heading, "Ability to Transmit Stresses," the outstanding requisite is tenacity; next would come high elastic limit and then high ultimate strength. From a theoretical point of view ductility is not a factor except to allow for irregularities of manufacture or inaccuracy of design. Nevertheless I would include ductility as a minor requirement. Under "Resistance to Deterioration in Service" would come resistance to corrosion, to corrosion fatigue, to mechanical fatigue, and possibly to shock. Under "Ability to Withstand Accident and Abuse" would come a high factor of safety in the design, and ductility. Finally, under "Ease of Fabrication" would come such properties as strength, ductility, machinability and others. Looking at a welded joint in this way, ductility is a minor factor of the first classification, does not enter into the second, and is a major factor only of the third and fourth. Or to sum up, such an analysis seems to agree very well with the statements of Professors Moore and Adams and most of the other authors who have taken a definite stand, that while ductility is an important element, extreme ductility is not necessary, and, I may add as my own conclusion, is a minor element as compared with first, a sound design; second, the choice of high grade materials; third, careful attention to fabrication and finally, thorough proof testing before use.

Ductility: A Measure of Cleanliness

By E. CHAPMAN

✦This paper was presented at the Symposium on Ductility During the Annual Meeting of the American Welding Society held in New York, April 27th to 29th, by E. Chapman, Director of Research & Engineering, Lukenweld, Inc.

FOR some little time, I have felt that the scope of my activities has far transcended my definite knowledge of the variables with which I am dealing. Whatever abilities I may have as a mathematical analyst have been left so far behind on many occasions that I pause to marvel at the infinite orderliness of Nature. However, my recoveries are fairly rapid. To cover situations such as these there has arisen down the ages a factor of ignorance whose numerical value lies somewhat between five and ten and this is the insurance policy which the engineering profession has issued to itself.

I have put mental question marks behind six topics: 1, Materials; 2, Stress Distribution; 3, Impact Loads; 4, Vibratory Loads; 5, Thermal Loads; and 6, Plain Overloads. I hold but little hope of reducing the size of the question mark behind 3, 4 and 5; no hope at all for item number six; but I wish to report a slight progress in items one and two.

As an example of what may happen in the realm of materials, note in Fig. 1 the metallurgical damage alongside a weld. We have partially hardened metal in a sorbitic condition and large overheated grains. I immediately wonder how this component of my structure will stand a severe impact or heavy overload. My grasp of the situation is further confounded by the fact that I once found martensite alongside a weld of this type.

Figure 2 shows a type of stress distribution which is in every day use. It is the stress distribution in an impure steel whose continuity has been badly distorted by the random distribution of a number of graphitic flakes. I have often wondered what I meant by the "average stress" in a piece of cast iron. Not knowing what maxi-

mum stresses exist, I work cast iron at a load of 2000–3000 lb. per sq. in. since I know from experience that this material will break at about 24,000 lb. unit stress and in addition behaves badly under impact. The steel in cast iron has not been well favored by nature for a life of hard work and we, therefore, in our calculations, lighten the burden upon this material. I sometimes wonder what sort of an engineering profession could be built if engineers had to go through a disciplinary period in which they were only allowed to use ropes for tension and concrete for compression. With such a background the advent of steel would be hailed in a spirit of reverence. The handicap under which steel is working in cast iron is not any worse than the occasional handicap imposed on steel by the people who use it. I am quite sure that, careful as I may be, some day I will pile up an infinite stress on some little forlorn cubic inch of steel and it is, therefore, hopeless to place at my disposal materials that are merely stronger. But I do not lose much sleep over these facts, because the steel which I am using is ductile.

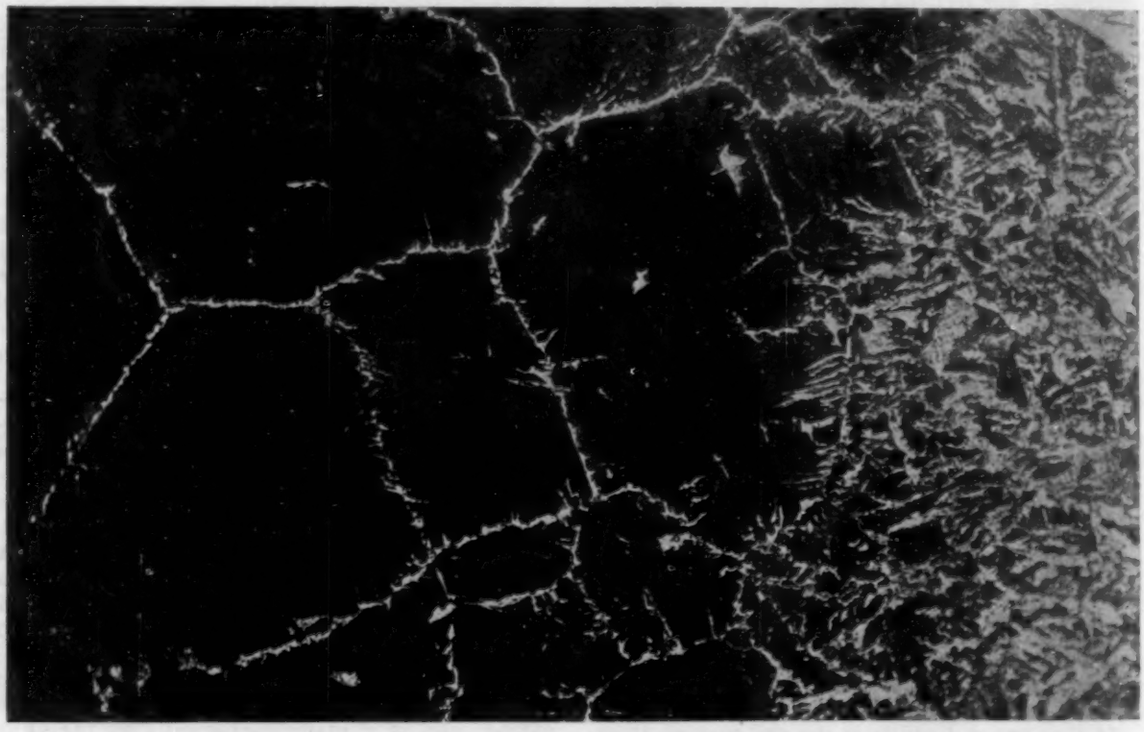

Fig. 1—Metallurgical Changes Due to Welding

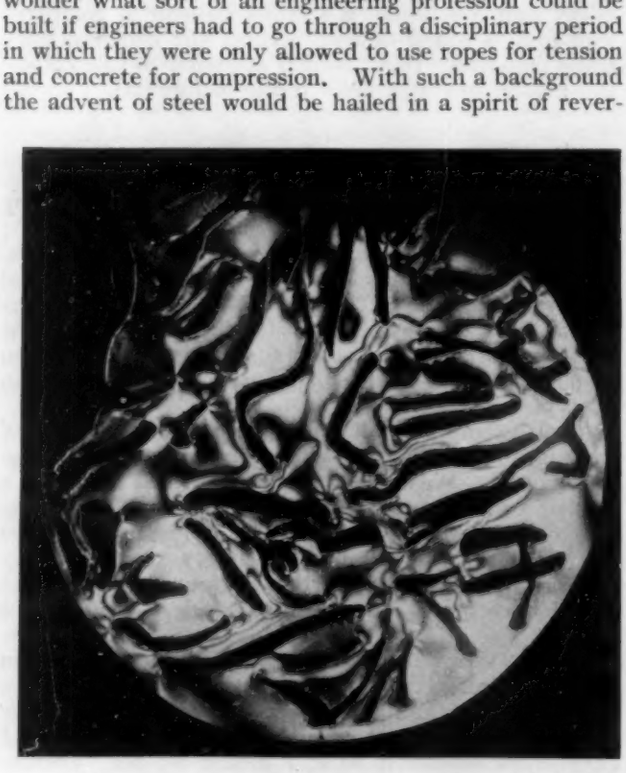

Fig. 2—Stress Distribution in Impure Steel

Figure 3 sums up an exhibition of this ductility in an actual structure. The nature of the job, a large C-frame press, involves a very uneven distribution of stress. The critical point, however, is the only one in which I am interested and this has been located through photo-elastic analysis and subsequently explored with strain gages. The curve marked "critical" gives the stress-load behavior of this point, while the curve marked "average" delineates the behavior of the remainder of the press. The steel at the critical point is doing what we failed to do when we engineered the structure: it is incorporating a larger radius at the point of maximum stress, through its ability to behave plastically under an overload.

An even more interesting case where the ductility of the material saved the structure right to the point of ultimate failure is illustrated in Fig. 4. Two fillet welds have been used, placed in the usual manner, to develop the strength of the one-inch plate. The plates were butted tightly together. The right hand side of Fig. 4 shows the concentrations which exist at the root of the weld due to the unwelded portion. It is a rather graphic picture of how poorly engineered this particular job is when regarded from the standpoint of the imposed loading—that of tension. The first sign of yielding on the steel specimen when pulled in a testing machine was at the places predicted in the photo-elastic study. This yielding and stretching continued until a combination of an increased radius at this point, with the attendant strain hardening of the weld metal, compensated for the

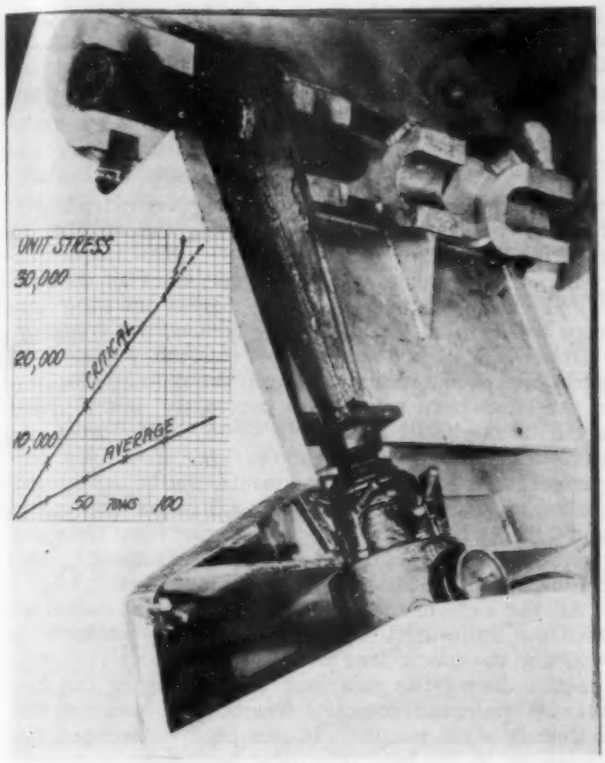

Fig. 3—Ductility in an Actual Structure

lack of engineering on this joint. Plastic yielding then stopped at the "hot spot," and the bar subsequently necked and broke some four inches away from the joint. This structure corrected itself in spite of the engineer. While this was not a joint in one of the poorly fitted tension members of some large bridge, we might find it fitting and proper to bow our heads in silence for thirty seconds.

Figure 5 illustrates a butt weld in which the weld metal is placed upon a similar "hot spot" due to design. These butt weld specimens were not welded entirely through. The weld metal in specimen on the top meets Boiler code requirements for Class 1. The specimen on the bottom is welded with Class 3 weld metal: a bare-wire electrode. The photo-elastic study in the center illustrates the stresses to which this type of weld is subjected. Once again we have severe concentrations at the roots of the welds and it would be useless to talk of "average stress" under conditions like these in as much as the stress ratio is probably as high as six. The ductile specimen, however, was more nearly able to approach the values to be expected of this class of metal simply because of the fact that it was able to readjust its contour so that the average stress became more and more significant as the metal stretched. The oxidized bare-wire weld metal was not able to approach the values to be expected of this material since it could not remove the curse which had been built into it. The unit stresses which were developed in these two welds were 72,000 lb. per sq. in. based upon the actual area of the ductile weld metal and 42,000 lb. per sq. in. based upon the actual area of the oxidized weld metal.

While all this illustrates and summarizes some of the

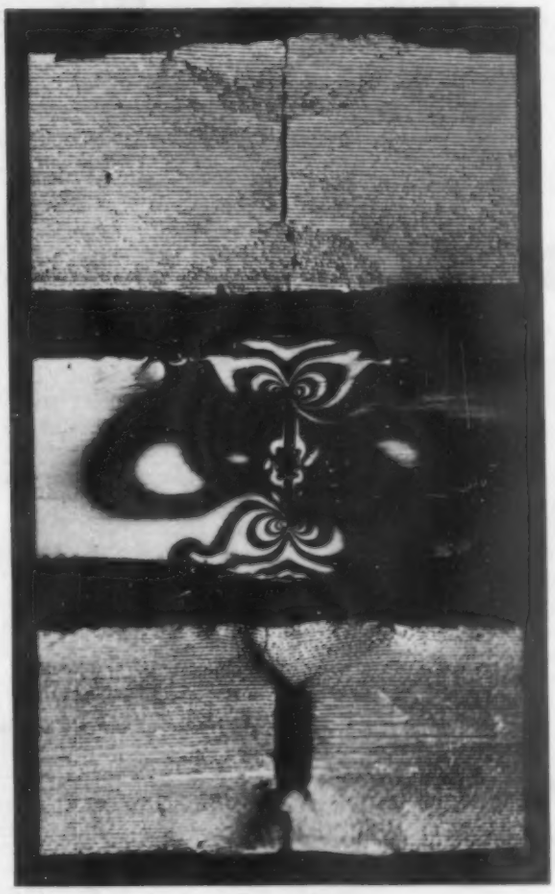

Fig. 5—Butt Weld

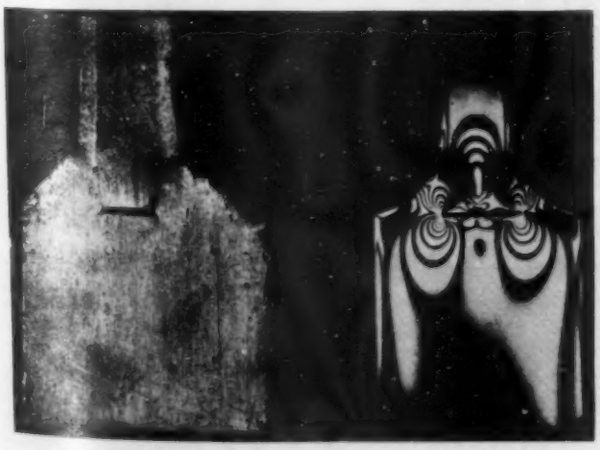

Fig. 4—Study of a Fillet Weld

beneficial effects of ductility in the true sense of the word, it means nothing to me in my present work. The actual stretching of the metal in the throat of the punch press in relieving itself, if occurring in a finished press, would utterly ruin the job by destroying the alignment. So I cannot count on that. If the T weld which was illustrated happened to be the top and side flange of a Diesel engine my structure would again become useless if such a deformation took place. Plastic set in the type of equipment with which I am dealing would be absolutely ruinous to the finished machine. I am much more interested in a high elastic limit, and a high fatigue strength and it is for these reasons that I want ductile material in my weld metal. I want clean steel. I do not want dirty oxidized steel. I want a high tensile strength: I do not want low tensile strength. I want a high elastic limit and I want the material to behave elastically up to its elastic limit. I want an endurance limit under re-

peated stress of 28,000 lb. per sq. in. as against 12,000 lb. in the oxidized weld metal which we formerly used. I want a material whose fatigue data do not announce its unreliability by pronounced "scatter." In the salt water application of welded steel Diesel frames I want welds with a high corrosion fatigue, which again means clean steel. I cannot use dirty steel with any degree of assurance on any of these items. I must have clean steel in my welds. The testing laboratories have a word for it: Ductility.

Welding and Heat-Treating Alloy Steel Locomotive Frames

By W. A. NEWMAN *and* C. F. PASCOE

†Mr. Newman is Mechanical Engineer for the Canadian Pacific Railway, and Mr. Pascoe is Superintendent of the Canadian Steel Foundries, Inc., Montreal, Canada. This article is reprinted from *The Iron Age*, Jan. 28, 1932.

BOTH oxyacetylene and electric welding are used in the ordinary locomotive shop and considerable information has been secured as to the effect of these methods in actual shop practice; in fact, it was due to the extensive local hardening that occurred with the oxyacetylene torch that the Canadian Pacific Railway Co.'s specification for main frames requires that risers be cut off at least 2 in. above the surface of the frame and the balance removed by planing.

Figure 1 shows the approximate effect of both single and double layers of low-carbon welding wire deposit on a low-carbon nickel steel casting containing 0.97 per cent manganese. With the single deposit the hardening effect extended only $^{3}/_{32}$ in. below the surface of the steel as determined on a Rockwell machine. The hardness was a maximum just at the outer junction of the deposit and the casting. In the case of the two layers of deposit, conditions were the same except that the hardness affected the steel casting to a total depth of $^{7}/_{32}$ in.

As would be expected, on account of the greater volume of heat, the oxyacetylene weld hardened the casting to a greater extent, the hardened zone extending $^{1}/_{2}$ in. from the junction of the deposit and the casting. As shown in the illustration, the effect of oxyacetylene welding was determined by filling in a 90-deg. vee extending $^{5}/_{8}$ in. into the casting, the deposit being the same as was used for the electric welding.

Figure 2 shows exactly the same tests as shown in Fig. 1 except that the casting was as an alloy steel very widely used for locomotive frames, but containing 0.28 per cent carbon and 0.82 per cent manganese. The effect of carbon and manganese on the welding properties of steel has been referred to previously, but it is well again to emphasize that for a so-called fool-proof steel that will stand up under abuse, low-carbon, low-manganese steels give the best results, and that the low-carbon nickel steel which contains 0.14 per cent carbon and 0.69 per cent manganese is superior from the standpoint of non-hardening and resistance to impact to steels containing high carbon and higher manganese.

All the experiments referred to above in connection with the uniform strength of steels were conducted in 1927 and the conclusions arrived at have been verified by practice during the past four years. During this time over 200 pairs of locomotive frames have been cast with extremely good results. It has been determined that variations in the heat treatment have been of material assistance in further developing the properties of the steel, and changes have occurred during four years' practice which have given improved results over the earliest frames cast.

The desired results aimed at were a minimum yield point of 50,000 lb. per sq. in., a minimum elongation of 30 per cent and a minimum reduction of area of 50 per cent. These results have been secured on a majority of the frames cast. The average from 2650 test coupons is as follows:

Yield point—49,796 lb. per sq. in.
Tensile strength—81,237 lb. per sq. in.
Elongation in 2 in.—30.3 per cent.
Red. of Area—61.2 per cent.

Heat Treatment to Secure Best Results

The heat treatment being followed at present is:

1. Heat to 1800° F. for 2 hrs. per inch of cross-section.

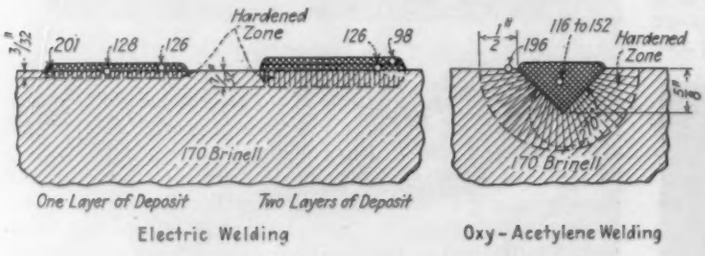

Fig. 1.—Approximate Effect of Both Single and Double Layers of Low-Carbon Welding Wire Deposit on a Low-Carbon Nickel Steel Casting Containing 0.97 Per Cent Manganese

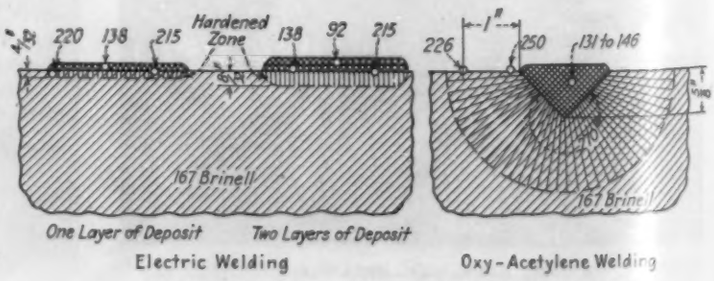

Fig. 2.—Same Tests as in Fig. 1 Except That the Casting Was an Alloy Steel Widely Used for Locomotive Frames

2. Heating of 1400° F. for 2½ hrs. per inch of cross-section.

3. After the above treatment, a trial test coupon is pulled and if the desired results are not secured, frames are given a drawback treatment from 1000° to 1200° F. for 2½ hrs. per inch of cross section.

Experience shows that although the long drawback treatment does not spheroidize the carbides to any extent, in nickel steel it still confers extra ductility to the steel without too much loss of strength. If it is desired to meet the strength limitations of 50,000 lb. per sq. in. minimum yield point, it will be found that a chemical composition consisting of carbon 0.18 per cent to 0.19 per cent, manganese 0.90 to 0.95 per cent, and nickel 2 to 2½ per cent will give the required results if properly heat treated.

To illustrate the value of the drawback treatment, the following results after second and third treatment may be of interest:

	Second Treatment 1450° F. Cooled in Air	Drawback at 1200° F.
Yield point, lb. per sq. in.....	57,800	50,460
Tensile strength, lb. per sq. in.	99,800	83,860
Elongation, per cent.....	25	31.6
Reduction of area, per cent...	47.7	65.8
Brinell No.....	197	156

The chemical composition of the particular steel for which the above results are quoted is carbon 0.20 per cent, manganese 0.95 per cent and nickel 2.38 per cent.

The above results, which constitute a summary of steel secured since 1927, are all based upon a material giving a minimum yield point of 50,000 lb. per sq. in., which is being obtained in all frames purchased at the present time. It has been found, however, that the higher physical properties have only been obtained at the expense of other qualities of the steel. Figure 1 shows the hardening effect of welding on steel of 52,000 lb. yield point. While these results are generally superior to higher carbon steels, yet nevertheless they are not as good as the original test steels produced in 1927 and listed as steel "G."

Impact Value and Yield Point

In addition to the increased hardening tendency, there has been a reduction in impact value, and although present impact values are considerably superior to other steels tested, nevertheless, to produce the same results as obtained for steel "G," the manganese should be kept as close to 0.70 per cent as possible and the carbon as low as can be commercially worked to, say, approximately 0.16 to 0.18 per cent. This steel is considered as being the toughest and most fool-proof steel for railroad purposes that can be produced and is preferred even to the steels at present being used if design requirements do not require the higher yield point, although it is debatable as to whether or not a somewhat lower strength steel with greater resistance to impact and with less tendency to harden is not, in the long run, a stronger and generally all-round more desirable steel than that of higher yield point and less impact. Frames produced in the past four years have been cast at both the Canadian Steel Foundries in Montreal and the Dominion Foundries & Steel Co., Hamilton, Ont., and the results from both foundries have been uniform and consistent.

Metallurgy Closely Checked

All the foregoing has related to the physical properties of the material. The metallurgical end was also very closely studied, not only from the standpoint of the proper melting of the steel and the pouring at the proper temperatures, but from the grain structure of the finished material. Every test specimen tested throughout the cross section of the test bars was polished and photomicrographs were secured. In addition, the entire cross section of the 6 × 6-in. section was polished and investigated under the microscope. Space does not permit the publishing of all the photographs made.

It may be said without qualification that the results secured, both from the foundry and the users' viewpoint, have been uniform and satisfactory. There is not a single record of a failure of a frame produced of the selected grade. The material is as readily machinable as any other grade of material and is even more fool-proof than straight carbon steel castings from the standpoint of being abused.

When all is said and done, this investigation of cast steels has only paralleled the conclusions arrived at with other grades of steels which have shown that the most desirable grades for railroad use are as nearly pure iron as the various processes of steel making will permit with the introduction of suitable alloys to give the desired strength from the standpoint of design requirements with, of course, maximum ductility, toughness and resistance to shock.

President's Annual Report on Societies Activities

(*Continued from page 4*)

Society's cash balance at the time of closing the books, March 31, 1932, was $3049.08, or an increase in cash balance over that at the time of closing on March 31, 1931, of $1399.10. In addition to the above there was on hand in a separate bank $559.60, covering the Miller Memorial Medal Fund. The value of the salable printed matter on hand was $2500.00, as against a like amount at the close of the books March 31, 1931.

Present worth of your Society as of March 31, 1932—$14,863.44 as against $13,517.65 on March 31, 1931, or an increase in worth of $1345.79.

A detailed financial statement will be presented to the Board of Directors at the Annual Meeting on the night of April 27, 1932. It will also be published in the Society's JOURNAL as usual, and there is on file at the Headquarters of the Society, the usual Annual Report of the Certified Public Account, this report dated April 8, 1932.

Journal

The editor of the Society's JOURNAL, who is also the Secretary of the National Meetings and Papers Committee, in his report to the Meetings and Papers Committee, gives the following very interesting data to the effect that as a result of an analysis of the statement prepared by the auditor for the year ending March 31, 1932, the following figures are produced covering amounts received from subscriptions to the JOURNAL, for the several years, as follows:

1928.....	$ 967.14
1929.....	1327.87
1930.....	1797.00
1931.....	2787.23
1932.....	3226.43

The above showing should be encouraging, especially in view of the fact that your Society's growth in subscriptions is better from a percentage standpoint than that

of the journals of practically all other societies. From the report of the Chairman of the Meetings and Papers Committee, it is evident that special efforts have been made by the Committee during the past year to balance the number of papers published in the JOURNAL as between the various processes of welding. While this balance has been maintained, it has involved at times considerable additional work on the part of the Committee and the Editor.

The 1931 bound JOURNAL is the first to appear in its present size, and including its covers, it comprises a total of 788 printed pages.

Meetings

As in previous years the two principal meetings arranged by the Meetings and Papers Committee have been the Fall and Annual Meetings of the Society.

The Annual Meeting was held, as is customary, in New York in April 1931. The Annual Dinner was held at the Hotel New Yorker and was of the stag variety. During the Annual Meeting a very fine program of technical papers was presented and as usual many of the Committees took advantage of the presence in New York of their out-of-town members and held meetings.

The Fall Meeting was held in Boston, September 21–25, 1931. There was a registered attendance of over 350 members and guests, and in spite of the adverse business conditions, the attendance at technical and other sections compared very favorably with those of other years. There were nineteen technical papers presented, covering a wide variety of subjects. The entertainment features were unusual, especially those features that were arranged for the ladies attending the meeting.

The Fall Dinner at the Copley-Plaza Hotel was among the best planned and best attended of the Society's dinners to date. Many noted and honorable guests were present, the speaker of the evening being His Honor, Mayor Curley of the City of Boston.

Sections

The number of local sections is the same as reported on March 31, 1931, although a number of inquiries have been received from various localities, particularly in the West and South in regard to the formation of new sections. All of these have been encouraged to secure the necessary number of members to permit of the formation of such sections, and it appears that during the first half of the Society year 1932, there should be at least one, and possibly two or three additional sections formed.

In some localities, section activities have been a little slower than in past years, this due in some cases to inability to secure suitable programs, and primarily to general business conditions, where it was not possible to induce members to take as active an interest in section affairs, as in times when business conditions are on a higher plane.

It seems proper here to call special attention to the activities of the New York Section, which contrary to the belief of many members, is entirely independent of the parent body, or at least as independent as any other section.

Referring to a report from the Chairman of the New York Section, it is encouraging to note that during the past year the Officers and Executive Committee of that Section carried forward the good work foundations for which were laid in previous years, and that in addition to the regular meetings, seven specially arranged meetings were held and that these were addressed by nationally known speakers and that the average attendance of these meetings was 370. Also, that the Section operated well within the finances of its budget allowance.

Society Committees

During the past year, several committees have completed their work and have been discharged with thanks, and several new committees have been appointed and in such cases as they have been able to function, reference to their work will be included herein.

Committee on Building Codes.—The report of the Chairman of your Committee on Building Codes advises that the main Committee held a second meeting in Boston during the Fall Meeting of the Society and that there is a meeting scheduled for April 26, 1932, in New York. Also that numerous sub-committee meetings were held.

Code for Resistance Welding of Structural Steel.—The subcommittee on this subject has submitted a draft of its recommended code, copies of which were distributed to all members in February 1932. This draft is scheduled for discussion by the main Committee at the April meeting.

Code for Welding Low Pressure Tankage.—As a result of a canvass made by the Secretary, report was made to the Executive Committee of the Society that there was no general demand for a code on this class of products, and that information on which such a code could be based was not available. Accordingly, the main Committee was relieved of this assignment. The data compiled by the subcommittee were published in the January 1932 issue of the JOURNAL, together with an invitation for papers describing current practice in this field.

Code for Welding Low Pressure Piping.—The issuance in October 1931, of a tentative draft of a code on Pressure Piping, prepared by a committee of the Society in cooperation with the A. S. M. E. has raised some question as to whether an additional code, dealing only with low pressure work, is required. This matter is scheduled for discussion at the April meeting.

Code for Fusion Welding of Structural Steel.—This refers to Code 1, Part A, already adopted by the Society. Suggestion for modifying the wording of the clause relative to painting will be discussed at the April meeting. The changes purport to make the use of linseed oil permissive rather than mandatory, and to omit reference to number of coats of paint.

Construction Safety Code.—A subcommittee was appointed to cooperate with Subcommittee No. 5, U. S. Department of Commerce, in the preparation of a section relating to safety in welding and flame-cutting processes employed during the construction or demolition of buildings. The report of this subcommittee has not yet been received.

New York City Building Code.—The situation is covered by a separate report made by the Chairman as representative of the Society on the Advisory Committee of The Merchants' Association.

Other Building Codes.—The use of welding has been permitted by several cities in addition to the 113 reported last September. Specific details are not available at this writing.

Mill Conditioning of Finished Rolled Steel.—The work of the subcommittee on this subject was handled by correspondence. A number of specimens, of both ordinary and silicon grades of steel, were prepared and tested by Carnegie Steel Company. The tests included the effect of punching through steel that had been conditioned by a welding process. It is believed that these were the first tests made to determine the punchability of weld metal. Copies were distributed to all subcommittee members.

Several tentative drafts of a proposed specification were prepared and discussed with steel mill representatives. Agreement seemed to be within reach except as to the propriety of including a requirement for the qualification of individual welders, this requirement being definitely opposed by some of the mills. The point in controversy was referred to the Executive Committee of the AMERICAN WELDING SOCIETY who supported the Chairman in insisting that any specification sponsored by the Society must include qualification requirements. As constructive action along this line did not seem feasible, it was decided to leave in abeyance the drafting of a specification, and to await further developments.

In the fall of 1931 a number of structural engineers and steel manufacturers, at a meeting in Chicago, agreed on a specification for the conditioning of surface imperfections. This specification has been endorsed by the American Institute of Steel Construction by inclusion in the latest edition of its Handbook. It is identical with that drafted by the Chairman except that it omits all qualification requirements. It is proposed to observe the working out of this specification.

Welded Construction of Railway Monorail.—A subcommittee was appointed to comment on a private specification for this field. It includes the question of safe loads on welded joints subject to variable stress. The report of the subcommittee has not yet been received.

Highway Bridge Construction.—At the request of the Executive Committe of the Society, the Chairman has suggested to the American Road Builders Association a number of names for membership on its proposed Committee on Welding for the Construction, Maintenance and Reconstruction of Highway Bridges. No advice has yet been received of the organization of the proposed committee.

Committee on Revision of Nomenclature, Definitions and Symbols.—Since the last Annual Meeting, your Committee on the Revision of Nomenclature, Definitions and Symbols has completed its work with Subcommittee No. VIII on Welding of Sectional Committee on Electrical Definitions of the A. S. A.

Assistance has also been rendered to the A. S. M. E. Boiler Code Committee in the nomenclature incorporated in its new Code.

Recently, at the request of the Marine Standards Association, work was started on the preparation of a set of standard symbols for marine work.

In addition to the above, several other bodies have been contacted with and arrangements are being made to supply

them with AMERICAN WELDING SOCIETY Codes and Standards.

Committee on Welding and Marine Construction.—Following is the report of the Chairman of your Committee on Welding and Marine Construction:

"The Subcommittee on Marine Boilers has completed 'Rules for the Construction of Fusion Welded Marine Boilers and Pressure Vessels' which will form Part B of the code. These rules are substantially identical to the 'Rules for Fusion Welding' given in the Power Boiler and the Unfired Pressure Vessel Codes of the American Society of Mechanical Engineers. Such modifications as have been made were to adapt the rules to marine practice and in some respects they have been made more stringent.

"These rules were approved by our Committee and by the Board of Directors of the Society at its meeting on January 5, 1932. The report of our Subcommittee on Marine Boilers was presented to the Committee to coordinate Marine Boiler Rules at its final meeting held in Washington on February 27, 1932, and was accepted for publication in the 'Rules for Construction of Marine Boilers and Pressure Vessels' with certain typographical changes in order to conform with the rest of the text, and a requirement was added that all Class 2 fusion welded pressure vessels shall be stress relieved in the same way as required for Class 1 vessels.

"Our Committee is submitting to the Board of Directors the foregoing rules in shape for publication, together with a preface outlining the scope of the proposed Marine Code."

Committee on Code of Principles of Conduct.—The Chairman of your Committee on Code of Principles of Conduct reports that it was unnecessary for your Committee to hold any meetings during the period covered by this report.

Revision of By-Laws Committee.—Report of the Chairman of your Committee on Revision of By-Laws covers revisions and recommended revisions to Amendment of Article 3, Section 3, of the By-Laws Involving Percentage of Annual Dues Returned to Sections. Amendment of Article 4, Section 4, of the By-Laws Involving Change of Directors at Large from 4 to 5. The report also covers the activities of the Committee in connection with the proposal to change the amount of refund to sections. It also covers the proposed revision of By-Laws covering the geographical location of the residence of Senior Vice-President.

Manufacturers' Committee.—Your Manufacturers' Committee, and especially its Chairman, has been very active during the past year. It has devoted a great deal of time to the subject of future exhibits and how they shall be handled and whether they shall be held annually or biannually. Satisfactory arrangements have been made for the exhibition in connection with the 1932 Fall Meeting of the Society in Buffalo.

Committee on the Use of Welded Parts for Machinery Construction.—Report from the Chairman of your Committee on the Use of Welded Parts for Machinery Construction is to the effect that during the past year three meetings have been held, one each in New York, Boston and Pittsburgh; that a fourth will be held on April 26th in New York. Further, that the Committee plans to have its proposed code in such shape that it can be offered for adoption as a result of the April 26th meeting.

Committee on Welding Code for Pressure Piping.—The Chairman of your Committee on Welding Code for Pressure Piping reports that during the Spring Meeting of the Society on April 23, 1931, a public hearing on the proposed Section on Welding—Code for Pressure Piping was held jointly with the Sectional Committee—Code for Pressure Piping of the American Society of Mechanical Engineers, who are sponsoring a similar code on this subject for the American Standards Association. At this meeting the proposed Section was printed and formally presented for the purpose of securing constructive suggestions. Marked interest was manifested at this meeting, attended by over 200 representatives of fabricators, users and manufacturers, as well as committee members of the two societies. Valuable criticisms and suggestions were received, which were abstracted from the minutes of the meeting and widely circulated to interested parties.

At the same meeting of the Society in Boston a joint meeting was held with the subcommittee of the A. S. M. E. charged with the responsibility of formulating the Section on Welding for the Pressure Piping Code.

By continued cooperation with the Pressure Piping Code Committee of the A. S. M. E., it is anticipated that a suitable AMERICAN WELDING SOCIETY Code will be formulated within a reasonable time.

Committee on Welding Code for Pressure Vessels.—The Chairman of your Committee on Welding Code for Pressure Vessels has submitted a lengthy report which covers the activities of your committee, its contacts with the A. S. M. E. and its handling of the many problems that have been laid before it by the A. S. M. E. These covered a wide variety of problems, numbering in all 21, and the solutions to these questions as submitted by your Committee Chairman were approved as submitted by the National Executive Committee.

Committee on Qualification Tests for Welders.—Your Committee on Qualification Tests for Welders is one of those previously referred to as having completed its work. The report submitted was one of considerable value and it is believed it will be widely used by educational institutions, etc.

Committee to Prepare Manuscript for Second Arc Welding Manual.—The Chairman of your Committee on the Preparation of Manuscript for Second Arc Welding Manual reports as follows:

"The Committee on the Revision of the Second Edition of the Arc Welding Manual has continued its work in collecting data and new material for the revised edition and has started work on the revision of the same. Resulting from the nature of the work, progress has been slow but to date four chapters have been completed.

"A second committee meeting is planned in conjunction with the 1932 Spring Meeting of the Welding Society at which time an attempt will be made to speed up this work so that the revised bulletin will be completed in the near future."

Committee on Standards of What Should Be Known by Welding School Graduates.—A report has been received from the Chairman of your Committee on Standards of What Should Be Known by Welding School Graduates, outlining what the graduates should have a working knowledge of and making certain conclusions and recommendations as to the class of schools, educational boards, etc., that should handle the training of welding students.

Special Committees to Render Assistance to Power Companies.—The Chairman of your Special Committee to Render Assistance to Power Companies reports as follows:

"The year's activities of the Committee appointed to render assistance to power companies has been confined in great measure to Detroit, Mich., and outlying cities in the district. Mr. M. P. Bailey, member of the Committee, and myself have functioned several times in assisting power companies throughout southern and central Michigan and, so far as I know, this is the extent of the activities of the Committee."

Committee on Establishment of Student Chapters in Universities.—The Chairman of your Committee on Establishment of Student Chapters in Universities reports as follows:

"The Committee on Establishment of Student Chapters has nothing new to report. My recent survey of the colleges showed that not only is it an inopportune time to establish new college chapters, but that the maintenance of student chapters in such organizations as A. S. C. E., A. S. M. E., etc., is proving very difficult."

Board of Trustees—Miller Memorial Medal.—The Chairman of your Board of Trustees—Miller Memorial Medal, reports as follows:

"I am pleased to advise that the 1931 Award of the Samuel Wylie Miller Medal has been made by the Board of Trustees to Professor Frank Pape McKibben for his outstanding work in the development of the art of Structural Fusion Welding.

"It is the decision of the Board that the announcement of the award be made at the Annual Meeting in April, and that the presentation of the medal be made at the Fall Meeting in Buffalo."

Century of Progress—World's Fair Centennial Celebration.—A report has been made by the Chairman of the Committee on Welding Exhibits covering the changes that have come about with regard to the proposed exhibition at the Century of Progress—World's Fair Centennial Celebration. The Chairman has also requested the opportunity of continuing his negotiations with the Century of Progress officials and your Executive Committee voted to accept the report and the offer of continuance of the Chairman's activities.

American Bureau of Welding

The Director of the American Bureau of Welding has submitted a five-page report covering the activities of the Bureau, pointing out the accomplishments from the Welding Society standpoint, and covering the work done by the several committees. This report also makes certain recommendations as to future financing of recommended new activities.

Structural Steel

The outstanding feature in the development of welding in 1931 was the presentation of the Structural Steel Welding Committee's Report epitomizing a five years' program of study and tests of various types of welded joints. The scope and thoroughness of the committee's work are so outstanding as to demand the attention of architects and engineers interested in steel construction. These results are now

available in book form in the AMERICAN WELDING SOCIETY's office and constitute an engineering classic. Commenting editorially on the report, the *Engineering News-Record* referred to it as the "Magna Charta of Structural Steel Welding."

The Program.—Of 2493 steel specimens, welded by 61 welders at 39 fabricating shops and inspected by 18 inspectors, 1098 were made and tested to determine the competency of welders, who, after thus qualifying, proceeded to weld 1395 specimens for use in the final investigation. Twenty-four laboratories, including college and commercial institutions, as well as the United States Bureau of Standards, tested the specimens for quality and strength.

Pressure Vessels

The Joint Pressure Vessel Committee of the American Bureau of Welding and the A. S. M. E., having completed its work, was discharged in November 1931, and as a result of the work of this joint body, welding is given a much more prominent place in the new Unfired Pressure Vessel Code of the A. S. M. E.

Welding Wire

During the past year the Chairman of this committee with such assistance as he could secure from the other members has given considerable attention to the revision and broadening of the welding wire specifications. The present specifications are limited in scope and are dependent primarily on chemical analysis. The new specifications give due recognition to the new types of welding wire, including proprietary wires, and are based primarily upon the physical properties of the resulting welds.

Standard Test for Welds

This committee has prepared a revised specification for standard tests for welds which was published in the November 1931 issue of the JOURNAL and will probably be reprinted very shortly in bulletin form.

Welded Rail Joints

The committee is devoting its attention to the preparation of a final report which will occupy several hundred printed pages, together with the preparation of a summary of conclusions.

Fundamental Research

As indicated previously this committee has issued a list of fundamental research problems in welding, together with a statement of the method of procedure of the committee. This has been printed in bulletin form and distributed widely among the various universities. It also appeared in the February 1932 issue of the JOURNAL OF THE AMERICAN WELDING SOCIETY.

Representation in Other Organizations

The following briefly outlines the activities of the AMERICAN WELDING SOCIETY representatives in other organizations during the year ending March 31, 1932.

A. S. M. E. Boiler Code Committee—American Welding Society Conference Committee.—Your Conference Committee has cooperated with the A. S. M. E. Boiler Code Committee during the past year and with the approval of the AMERICAN WELDING SOCIETY Executive Committee it has transmitted to the Boiler Code Committee of the A. S. M. E. action on 12 problems submitted.

A. S. T. M.—Your representative on the A. S. T. M. Committee covering Welding Wire specifications reports that it was decided at a meeting held in Cleveland Ohio, on March 10th, that before any action would be taken by the A. S. T. M. Committee they would await report of the AMERICAN WELDING SOCIETY Committee, which plans to meet, and if possible, formulate at least a tentative specification on April 27, 1932.

Reports are also available from your representatives to the A. S. T. M. covering activities of Subcommittee No. XXI of Committee A-XXI of the A. S. T. M. and relating to Specification A-78-30 Steel Plates of Structural Quality for Forge Welding; also tentative specifications A-89-31T for Steel Plates of Flange and Fire Box Qualities for Forge Welding. A further report relating to activities of Subcommittee No. XXI on Steel for Welding is to the effect that the Committee has expressed in its minutes that all that can be reasonably expected at this time, and possibly at this time next year, is that further data may be obtained on the effect of chromium and silicon on the fusion welding quality of steel.

A. S. A.—Your representative on the A. S. A. Sectional Committee on Welding reports as follows:

"I would advise that the A. S. A. Sectional Committee on Welding has reviewed and revised the A. I. E. E. Standards on Electric Arc Welding Apparatus and Resistance Welding Apparatus. The proposed revisions have been circulated to the Committee for final vote and it is expected that we will shortly be in position to recommend to the A. S. A. approval of those two standards as revised."

Your representative on the A. S. A. Sectional Committee on Safety Code for Construction Work, A-10, advises that since his appointment no meetings have been held.

Your representative on the A. S. A. Sectional Committee on Electrical Definitions reports as follows:

"In reference to the activities of the A. S. A. Sectional Committee on Electrical Definitions, please be advised that the Subcommittee of the A. S. A. Sectional Committee on Electrical Definitions which had in hand the preparation of definitions for welding terms has turned in a report recommending 152 terms for inclusion in the glossary being prepared by the Committee, each term being, of course, defined.

"This report has been approved by the main committee and the recommended terms will be included in the first edition of the glossary which, it is expected, will appear about the middle of this calendar year."

Your representative on the A. S. A. Technical Committee on the Standardization of Electric Welding Dies and Electrode Holders reports that no activities have taken place during the past year. One meeting was called, but due to insufficient attendance, the meeting could not be held.

A. E. R. E. A.—Your representative on the A. E. R. E. A. Committee No. 6, Standard Specifications for Filler Metal reports that he has attended a number of meetings of this Committee and that the Committee has given considerable amount of study to the Filler Metal Specifications prepared by the AMERICAN WELDING SOCIETY and that after an all-day meeting on March 18th, of this year, it was agreed to adopt the A. W. S. tentative draft submitted under date of January 16th.

Your representative points out very definitely that he has had 100% cooperation in his undertaking.

A. S. S. T.—Your representative on the A. S. S. T. Recommended Practices Committee reports that he attended two meetings of the Committee, one in Boston and one in Cleveland, and that the most important action was the adoption of a logical system of classification for all matters intended for use in National Metals Handbook, and which includes proper recognition of welding and flame cutting.

A. M. S. C.—Your representative on the A. M. S. C. reports that only one meeting has been held since his appointment and the only action at that time was the election of officers.

Merchants Association, N. Y. City.—Your representative on the Advisory Committee on Revision of Building Code for the City of New York sponsored by the Merchants Association of New York City reports as follows:

"No meeting of the entire Advisory Committee was called during the period in question, but a number of sessions were held by the various technical subcommittees, several of which I attended. In the Subcommittee on Fire-Resistive Construction clauses had been drafted that seemed to favor the makers of fire-proofed wood doors to the detriment of hollow metal door manufacturers who generally use a resistance process of welding. These clauses were amended along lines satisfactory to the metal interests.

"In December 1931, the work of all the subcommittees was completed, and the several sections were assembled by the Committee on Building Laws and Regulations, and approved by the Directors of the Merchants' Association who, early in January 1932, submitted the code in printed form to Mayor Walker.

"I consider that this code, as a whole, provides for the use of welding and flame cutting processes in a manner that is adequate and that should be acceptable to our society. A few desirable corrections of what were apparently editorial inconsistencies have been called to the attention of the Director of Research for the Association, who has indicated that they will be suitably amended.

"No official action has yet been taken by the Mayor looking to the submission of

the code to the Board of Aldermen for the purpose of holding public hearings. It is informally reported that the code may be referred back to The Merchants' Association for a re-consideration of the number of features to which opposition has been voiced."

N. B. of B. and P. V. I.—Your representative on the Executive Committe of the National Board of Boiler and Pressure Vessel Inspectors reports that during the past year he attended two meetings of the Executive Committee of the Board and that this Board has maintained its close relationship with the A. S. M. E. Boiler Code Committee and has rendered assistance in the handling of many problems which were mainly administrative in character.

Society Incorporation

A special committee was appointed for the purpose of investigating and later making the necessary arrangements for the incorporation of your Society, the matter having been laid before your Board of Directors as covered by my Annual Report for 1930.

It was found that the Society could be incorporated for a reasonable sum of money and would thereby benefit from the laws governing incorporated bodies. Your Committee worked long and diligently and their efforts were productive of the desired results, as is indicated by a Certificate of Incorporation duly certified by the State of New York, Department of State, date of filing recorded as the 15th day of February 1932. The original of this document, as indicated in a letter of February 17th from the attorneys handling the transaction, is on file in Albany, New York, while a duplicate has been furnished to Society headquarters.

Other Matters

As the length of this report must be within reason it becomes necessary to omit many of the details in connection with work of several committees, the chairmen of some of which have not had time as yet to report, and it will be noted that I have also omitted reports from your sectional representatives for the prime reason that in some cases the annual reports of the sectional representatives have been delayed, but it is felt that as previously referred to, these data will all be made available to you through your JOURNAL. It seems appropriate to omit those data which could only be of interest to a few.

In submitting to you this, my final report as your President, I want first to thank the entire membership of the Society for its successful efforts to hold together an organization that undoubtedly is of vast value to the individuals and industries participating in its membership, this holding together even in the face of such a trying period as we have encountered during the past year. I feel that it is with a great deal of pride that we can point to the fact that our membership, while not numbering as many as on March 31, 1931, has not shown a decrease to the number as shown as total membership on March 31, 1930, and I call your attention to the fact that I believe this to be due to the untiring efforts of those of your National officers and sectional representatives who are charged with the duty of maintaining membership and close cooperation with it.

It seems only fair to point out to you here that the paid employees in the headquarters of the National organization have responded willingly to the unusual demands on their services brought about by the present conditions and that they have accepted without complaint the necessary reduction in salaries occasioned by the Society's curtailed income.

Stress must be laid on the prompt and unselfish response from the various sections when it became necessary to curtail the amount of monies returned to the sections in the form of refund on dues, and it was only by virtue of the unselfishness of the sections and the various individuals referred to above that your Treasurer was able to render to you a financial report of as satisfactory a nature as that submitted.

It has been one of the greatest pleasures of my life to have served you for the past two years, and in retiring, I want to again thank you for the honor of not only electing me, but for the continued honor embodied in my re-election.

It was with more or less trepidation that I approached the close of my term of office, as I feared that I might have to turn over the affairs of your Society to my successor in a condition not comparable to the condition in which your Society's affairs were turned over to me, but again, due to the untiring efforts of your Treasurer, Assistant Treasurer, Secretary, Technical Secretary and other officers and representatives, I have been enabled to render you this report with the feeling that under existing circumstances our combined efforts have been productive of a fair return. Finally, allow me to say for the entire membership that, based upon its cooperation with me, I feel sure that it will offer to my successor as great help as I have been the recipient of, and that as times grow better, our Society will not only prosper, but that it will advance in size and prestige to a point where it will not only be recognized for its value, but to a point where membership in it will be the aim and goal of every individual in any way connected with the vast interests which it represents.

Respectfully submitted,

E. A. DOYLE,
President.

PACIFIC NORTHWEST WELDING CONGRESS

The Pacific Northwest Welding Congress and Show was held at the Public Auditorium of Portland, Oregon, April 28th to 30th. Twenty-five firms cooperated by taking space in the Exhibition Hall and displaying all kinds of welding equipment and arranging for active demonstrations. The program included lectures and discussions on welding topics in the afternoon and evening of each day. The Annual Banquet was held on Saturday night, April 30th at the Multnomah Hotel. The program included an address of welcome by Mayor George L. Baker of Portland; a response by Mayor M. G. Tennant of Tacoma, Wash., and addresses by Messrs. Geo. C. Dierking and H. J. Rogers. A series of some of the up-to-date motion pictures on welding were shown and technical papers were presented by the following: Paper on "Welding," by A. G. Bissell, Seattle, Wash.; "Modern Application of Arc Welding," by A. M. Candy, Westinghouse Elec. & Mfg. Co.; "Application of Cutting and Welding in the Lumber Industry," by W. E. Wiebenson, Linde Air Products Co.; "The Old Time Blacksmith," by Jimmie Cranna, Municipal Shops, Portland, assisted by John Gaarde, Tigard, Oregon; "The New Time Blacksmith," by W. P. Kellogg, Fred L. Huggins, Chas. Beckwith, Geo. Clark, E. R. Hodson of the Air Reduction Sales Company; "Practical Welding Methods," by H. B. Isings, Woodbury & Co.; "Hard Surfacing Methods," by Ralph S. Beeler, J. E. Haseltine & Co. (Discussion); "Laying Out Sheet Steel for Pipes and Fittings," by Joseph Farthingill, Longview Fibre Co.

Special thanks are due to the Officers, Executive Committee, Program Committee and Entertainment Committee for the success of this conference.

The Board of Directors of the American Welding Society at their Annual Meeting sent the following telegram:

> "The Board of Directors of the American Welding Society in session tonight wishes the Portland Section the greatest success in its regional congress and regrets that distances make it impossible to have representative present. We are with you in spirit."

METAL EXPOSITION

Technical programs of unusual quality will be sponsored by the seven societies and divisions cooperating in the Fourteenth Annual National Metal Congress and Exposition in Buffalo, the week of October 3rd.

The AMERICAN WELDING SOCIETY'S technical program promises to be one of the greatest in the history of the Society. A large number of research and practical papers have already been assured.

Other societies meeting at the same time are American Society for Steel Treating; Iron and Steel and Institute of Metals Divisions of the American Institute of Mining and Metallurgical Engineers; Iron and Steel Division of the American Society of Mechanical Engineers; Production Activity Division of the Society of Automotive Engineers; and the Wire Association.

Advance space reservations for the National Metal Exhibition have more than exceeded expectations, W. H. Eisenman, director of the Exposition, has announced.

PAST PRESIDENT DOYLE HONORED

Mr. E. A. Doyle, retiring president of the AMERICAN WELDING SOCIETY, has been appointed by Mayor Walker as a member of the City of New York Commission for the Celebration of the Two Hundredth Anniversary of the birth of George Washington. This committee has complete charge of the planning and arrangement for the celebration.

ELECTION OF OFFICERS

The following officers and members of the Board of Directors were elected at the Annual Meeting.

Officers

President—F. P. McKibben, Consulting Engineer, Black Gap, Pa.

Senior Vice President—A. E. Gaynor, J. A. Roebling's Sons Company, 83 Liberty Street, New York City.

Vice Presidents—New York & New England—H. N. Ewertz, Austin-Hastings Company, Cambridge, Mass.

Middle Eastern—A. F. Davis, The Lincoln Electric Company, Cleveland, Ohio.

Middle Western—H. S. Card, The Welding Engineer Publishing Co., 608 South Dearborn Street, Chicago, Illinois.

Directors at Large

Term of 3 years

C. A. Adams, Pierce Hall, Harvard University, Cambridge, Mass.

H. M. Hobart, General Electric Company, Schenectady, N. Y.

D. S. Jacobus, Babcock & Wilcox Company, 85 Liberty Street, New York City.

J. W. Owens, Consulting Engineer, Portsmouth, Va.

SECTION ACTIVITIES

BOSTON

The April meeting of the Boston Section was held Friday evening, April 15th, in the Engineering Societies Rooms. A varied program (including demonstrations, lantern slides and motion pictures) was offered to the members and their guests, and at the end of each paper there was ample opportunity for discussion. The program is given below:

Talk, illustrated with lantern slides—"Machine Gas Cutting," by W. F. Barron, Air Reduction Sales Co.

Demonstrations—"Experiments on the Quick Freezing Qualities of Liquid Air," by R. B. Brown, Air Reduction Sales Co.

Motion Pictures—"Oxwelding in Production," 1 reel.

Talk, illustrated with lantern slides—"Porosity in the Metal of Gas, Electric, and Thermit Welds," by H. R. Bullock, Mass. Inst. of Technology.

This was the first meeting of the Boston Section under its new officers. They hope to arrange a schedule of meetings for the coming season that will bring a large attendance to each meeting. Suggestions from the members as to subjects for meetings will be welcome, and carefully considered.

CHICAGO

More than eighty members and guests attended the April meeting of the Chicago Section held on the 1st at the Palmer House.

Claud S. Gordon and Wm. G. Praed of the Claud S. Gordon X-ray Laboratories, Chicago, were the speakers of the evening. They had prepared thirty radiographs of 5 × 6 in. weld specimens for discussion. This opportunity was given those interested in welding in Chicago district to see exactly what the X-ray has to offer in the way of weld inspection.

As an added feature of the meeting, the weld specimens, themselves, were given bend and nick-break tests, so that comparisons could be made between the three methods of testing welds.

The next meeting of the section will be held on May 6th, at 7:30, in the Palmer House. All those interested are cordially invited to attend.

NEW YORK

The next meeting of the New York Section will be held on May 24th at 8:00 P.M. in the Engineering Societies Building. "Stainless Steel" will be the subject of the meeting. The following are the papers to be presented:

"History, Classification and Metallurgy," J. H. Critchett, Vice President, Union Carbide & Carbon Research Laboratories, Inc.

Stainless Steel. "Available Types, Uses and Applications," C. A. Scharschu, Director of Research, Allegheny Steel Company; D. T. Haddock, Consulting Engineer, American Sheet & Tin Plate Company (Subsidiary U. S. Steel Corporation).

PHILADELPHIA

There were about a hundred present at the April 18th meeting of this Section, at which Mr. F. Eder, of the Robert W. Hunt Company, gave a very interesting talk on "Inspection of Welded Steel Framing in Buildings," and a lively discussion followed.

The May meeting will be held on the 16th in the Auditorium of the Engineers Club. Mr. F. V. David of the Applied Engineering Department, Air Reduction Sales Company, will present a paper entitled "Theory and Practice of Oxy-Acetylene Cutting," which will be illustrated with lantern slides. A revised and up-to-date edition of the film "Oxygen the Wonder Worker" will also be shown.

PITTSBURGH

Frank P. McKibben, Consulting Engineer, General Electric Company, on April 13th presented a paper on Erecting Steel Buildings and Reinforcing Wrought Iron and Steel Bridges by Welding before 300 men who attended a joint meeting of the Pittsburgh Section of the American Welding Society with the American Society of Civil Engineers, Pittsburgh Section of the Engineer's Society of Western Pennsylvania. In his discussion on welded steel buildings, Mr. McKibben mentioned several problems that remained to be solved such as the correct design of joints for certain purposes, whether to use coated or bare electrodes, the possible limitation of the application of welding for erecting steel buildings, etc. Of particular interest were two tables which he has compiled based on data obtained from his experience in erecting a number of large welded buildings. The one table listed such data as the pounds of electrode melted and wasted, actual hours of welders' time, total length of fillets, fillet deposited per ton of steel welded, etc. From this table he compiled a second table from which can be quickly calculated the welding man hours, pounds of electrodes required, number of welders and machines necessary and other pertinent data required for erecting a building requiring a known tonnage of structural steel.

The latter part of his discussion covered the strengthening of various types of bridges. He listed the reasons why bridges had to be reinforced and then showed slides of various structures explaining how the work had been accomplished by welding.

The architects, fabricators and city engineers in the audience asked Mr. McKibben many questions the answering of which developed much additional information.

The last meeting of the season will be held May 18th at the Fort Pitt Hotel at which will be presented two papers on oxyacetylene welding.

LOS ANGELES

The Los Angeles Section has been very active in various technical matters pertaining to local conditions involving the use of welding.

Pressure Vessel Code Committee.—Was formed to work with the State and Municipal Departments on pressure vessel codes and to promote the interests of welding. In this work they have cooperated with the Industrial Accident Commission, a State Department, in advising them concerning revisions to the "Air Receiver Orders" and the preparation of "Tentative Orders for Pressure Vessels, Other Than Air."

Piping Committee.—Has for its object the drafting of a code for pipe welding and to seek favorable local laws regarding its regulations.

Structural Committee.—Has for its object the incorporating in the building ordinances particular sections that deal with structural welding, rather than having each permit for a welded structure treated as a special concession.

The Los Angeles Section held a meeting on April 21st at the Miramar Hotel, Santa Monica. Seventy-one members and guests were present. Mr. J. J. Bruton introduced the speaker of the evening, Mr. John Weaver, Engineer, Douglas Aircraft Co., whose subject was "Aircraft Fuselage and Aluminum Tank Welding." Mr. Weaver dealt particularly with oxyacetylene welding, covering such subjects as safety in welds, training of welders, selection of materials, supervision of production, use of jigs and

heat treatment of welds. After the meeting the members and their guests inspected the plant of the Douglas Aircraft Company.

SAN FRANCISCO

The San Francisco Section held a meeting on April 29th, at which the speaker was Mr. Frank Maker of the Standard Oil Company who spoke on the subject, "The Recommended Unfired Pressure Vessel Code for the State of California."

Chairman Britton appointed a Nominating Committee consisting of George Raitt, Chairman; L. P. Henderson, C. B. Leahy, C. R. Owens and J. Peterson, who will select the officers for this Section and report back at the May meeting which will be held at the Russ Building on May 20th, at 7:15 P.M.

EMPLOYMENT SERVICE BULLETIN

SERVICES AVAILABLE

A-165. Electric welder desires position. Worked five years for A. O. Smith Corp. as electric welder in shop and field, also for the Smith Bros. Construction Co. on pipe line work, H. C. Price, Inc., Bartlesville, Okla., and on the Southern Fuel Company's 26" natural gas line. Experienced in use of covered electrodes and making bell-hole and overhead welds.

A-166. Electric Welder. Considered a first class operator. Thirteen years' experience both at home and abroad, of which ten years have been spent as a Foreman and Instructor. Passed tests for Class II, A. S. M. E. Code for Unfired Pressure Vessels. Excellent references.

A-167. Arc Welder with ten years' experience. High pressure, marine and boiler work.

A-168. Electric and Acetylene Welder. Ten years' experience. Pressure tank, structural steel fabrication, shopwork, etc.

A-169. Electric and Acetylene Welder. Fifteen years' experience.

Current Welding Literature

A discussion of Piping Design, H. P. Smith. Welding (March 1932), vol. 3, no. 3, pp. 179–182.

A Revolution in Joints, G. Raymond. Welding (March 1932), vol. 3, no. 3, pp. 163–165 & 187. An engineer paints a striking picture of what the welding processes are doing to promote production in all industries.

Airplane Manufacture. Welding Applied to Aircraft Construction, P. F. Taylor. Welding Journal (Jan. 1932), vol. 29, no. 340, pp. 18–20; and (Feb.), pp. 38–40 including discussion.

All-Steel Auto Bodies are Flash Welded. Steel (April 11, 1932), vol. 90, no. 15, pp. 31–33.

All-Welded Hospital Building Erected at Boston, Anthony S. Coombs. Welding (March 1932), vol. 3, no. 3, pp. 147–149. First shop and field welded municipal structure in this city required 492 tons of structural steel.

Application of Gas Welding on Nickel Plate Railroad, J. C. Miller. Welding (March 1932), vol. 3, no. 3, pp. 150–153. Substantial savings are effected in the locomotive, car and maintenance of ways departments.

Application of the Oxy-Acetylene Process in the Production of Motor Cars, R. E. Esch. Sheet Metal Industries (March 1932), vol. 5, no. 11, pp. 787–788 & 791.

Atomic Hydrogen Welding, S. Martin. Iron and Coal Trades Rev. (April 8, 1932), vol. 124, no. 3345, p. 599.

Automobile Body Manufacture. Welding in All-Steel Body Production, J. W. Meadowcroft and J. U. Paugh. Soc. Automotive Engrs. Jl. (March 1932), vol. 30, no. 3, pp. 143–7 and (discussion) 147–9 and 152. Welding procedure and equipment of E. G. Budd Mfg. Co., Philadelphia; application of flash and spot welding for various parts of body; examples of electrode set-ups; sedan has 2503 spot welds and 140 in. of flash weld.

Bridges of Electric Welded Construction. Electric Welding (Feb. 1932), vol. 1, no. 3, pp. 12–13.

Bridges, Railroad. Bridge Reconstruction by Electric Welding, L. N. E. R. Ry. Gaz. (March 4, 1932), vol. 56, no. 10, pp. 333 and 341. Two old and weak bridges carrying heavy traffic of Newcastle South Shields Branch have been strengthened to meet modern conditions; design of new floor; method of carrying out work.

Bridges, Steel Truss. Largest All-Welded Bridge Built in Czechoslovakia, F. Faltus. Eng. News-Record (March 24, 1932), vol. 108, no. 12, pp. 439–440.

Buildings, Steel. Welded Steel-Frame Buildings. Iron and Coal Trades Rev. (March 18, 1932), vol. 124, no. 3342, p. 476. Structural details of 160-ft. clear-span cantilever-type roof for all-welded steel-framed building; data on shop welds.

Coal Mines and Mining. Use of and Saving Effected to Acetylene and Electric Arc Welding, C. Lee. Ill. Min. Inst. Proc. Meetings (June 5–7 and Nov. 6, 1931), pp. 29–30 and (discussion) 30–31.

Concrete Reinforcement. Welding Reinforcing Steel in George Westinghouse Bridge. Eng. News-Record (March 24, 1932), vol. 108, no. 12, p. 435.

Cutting Down and Re-Erecting Gas-Welded Tanks Economically, M. K. Allen. Welding (March 1932), vol. 3, no. 3, pp. 158–160.

Diesel Engines, Marine. Electric Welding in Marine Machinery, C. H. Stevens. Brit. Motor Ship (Feb. 1932), vol. 12, no. 144, pp. 454–457. Application of electric welding to Diesel engines.

Diesel-Electric Locomotives. All Welded Switching Locomotive, R. V. Devlin. Gen. Elec. Rev. (Feb. 1932), vol. 35, no. 2, pp. 110–112. Seven 60-ton 300-hp. Diesel-electric locomotives for switching service at Bush Terminal, New York City, completed at Erie plant of General Electric Co.; mechanical portion, including cab, underframe, and trucks, is fabricated entirely from structural steel shapes and plates and arc welded throughout; there are no rivets, and bolts are used only for portions requiring occasional removal or renewal.

Electric Welding, Arc. Arc Welding for Pressure Vessels, G. G. Landis. Boiler Maker (March 1932), vol. 32, no. 3, pp. 59–61. Practical review of requirements for successful welding in any field or application; types of electric welded pipe used for test; welding tests.

Electric Welding, Resistance. Fundamental Data Pertaining to Resistance Welding, G. A. Hughes. Welding (Feb. 1932), vol. 3, no. 2, pp. 84–87; and (March), no. 3, pp. 154–156.

Electric Welding, Resistance. Twin-Spot Welding Process, K. Ruppin. Eng. Progress (Feb. 1932), vol. 13, no. 2, pp. 38–39. With new "twin-spot" welding process, electrodes are not placed opposite each other as before, but side by side, and as name indicates, two spots are simultaneously welded by both electrodes being pressed upon part to be welded.

Electric Welding in Ship Construction. Electric Welding (Feb. 1932), vol. 1, no. 3, pp. 19–21.

Fatigue Strength and Strain Relief, C. H. Jennings. Welding Engineer (Feb. 1932), vol. 17, no. 2, pp. 39–41; and (March), no. 3, pp. 38–39.

Girders, Large Welded. Engineering (March 18, 1932), vol. 133, no. 3453, p. 351.

History and Development in the Art of Welding Ferrous Metals. Part III. A. J. Moses. Combustion (April 1932), vol. 3, no. 10, pp. 28–33.

House Frame Entirely Arc Welded, A. F. Davis. Sheet Metal Industries (April 1932), vol. 5, no. 12, pp. 861–862.

Houses, Steel. Six-Room Brick and Steel House Completely Arc-Welded. Construction Methods (April 1932), vol. 14, no. 4, pp. 28–29.

Hydraulic Turbines. Cavitation of Hydraulic Turbine Runners. Engineering (March 25, 1932), vol. 133, no. 3454, pp. 366–367.

Industrial Plants. All-Welded Steel Framed Building. Engineering (March 18, 1932), vol. 153, no. 3975, pp. 310–312.

Iron and Steel Plants. Maintenance Welding in Iron and Steel Plants, E. L. Quinn. Sheet Metal Industries (Feb. 1932), vol. 5, no. 10, pp. 721–722. Also in Canadian Machinery (Jan. 21, 1932), vol. 43, no. 2, pp. 34 and 36–37; and (Feb. 4), no. 3, pp. 25–26 and 28.

Jigs and Fixtures Made of Welded Steel, J. R. Weaver. Metal Progress (March 1932), vol. 21, no. 3, pp. 32–36. Advantages of welded jigs and fixtures; production methods and equipment at East Pittsburgh Works of Westinghouse Elec. & Mfg. Co.

Manganese Steel. New Welding Material for Manganese Steel, J. H. Hall. Iron and Coal Trades Rev. (April 1, 1932), vol. 124, no. 3344, p. 550.

Marine Boiler Repair, F. Woodward. Electric Welding (Feb. 1932), vol. 1, no. 3, pp. 5–7.

Methods of Controlling Arc Blow, R. W. Holt. Welding Engineer (March 1932), vol. 17, no. 3, pp. 40–42.

Office Buildings. When Driveway Had to Be Widened, F. P. McKibben. Welding Engineer (Feb. 1932), vol. 17, no. 2, pp. 47–49.

Oxyacetylene Cutting. Effects of Machine Gas Cutting on Steel Plates, L. M. Curtiss. Blast Furnace and Steel Plant (March 1932), vol. 20, no. 3, pp. 270–271.

Oxyacetylene Cutting. Machine Gas Cutting, L. M. Curtiss. Metallurgist (Supp. to Engineer) (Feb. 26, 1932), pp. 29–30.

Oxyacetylene Cutting. Some Methods and Effects of Machine Gas Cutting, L. M. Curtiss. Iron and Steel Canada (Feb. 1932), vol. 15, no. 2, pp. 13–14 and 24. Also in Sheet Metal Industries (April 1932), vol. 5, no. 12, pp. 856 and 879.

Oxyacetylene Tips (April 1932), vol. 11, no. 4. Oxwelded Bodies Increase Pay Loads. Hard-Facing for High Pressure Work. Salvage by Cutting. Inspection Made Easier. A Floating Home.

Oxyacetylene Welding. New Welding Blowpipe Has Been Developed for Oxyacetylene Welding, T. W. Greene. Oil and Gas Jl. (April 21, 1932), vol. 30, no. 49, p. 48.

Oxyacetylene Welding in the Brewing Industry, Lewis Davies, Mechanical and Welding Engineer. (Feb. 20, 1932), vol. 6, no. 2, pp. 34–38.

Pipe Lines. Discussion of Piping Design, H. P. Smith. Welding (Jan. 1932), vol. 3, no. 1, pp. 43–46; and (March), no. 3, pp. 179–82.

Piping Specification for Power Stations, Welded. F. W. Martin. Welding (March 1932), vol. 3, no. 3, pp. 176–178.

Pipe Lines. Welding Methods for Header Fabrication. Contract Rec. (March 23, 1932), vol. 46, no. 12, pp. 332–36. Application of oxyacetylene process to fabrication of headers for piping installations; design features; fabrication of headers.

Pipe Welding—Big Contracts Can Be Made Bigger, Elmer H. Smith. Welding Engineer (March 1932), vol. 17, no. 3, pp. 32–34.

Pipe Welding. Methods of Welding Pipe, E. R. Benedict. Nat. District Heat. Assn.—Proc., vol. 22, meeting June 2–5, 1931, pp. 328–36. Brief survey of various processes of welding obstacles in welding field; characteristics of pipe welding methods.

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Rails. New Arc-Welded Continuous Rail Joint, W. D. Chapman. Commonwealth Engr. (March 1, 1932), vol. 19, no. 8, pp. 293–294.

Resistance Welding, Frank O'Brien. Mechanical and Welding Engineer (Feb. 20, 1932), vol. 6, no. 2, pp. 39–44.

Resistance Welding Transformers, P. W. Fassler. Welding Engineer (March 1932), vol. 17, no. 3, pp. 35–38.

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Shipbuilding. Electric Arc Welding in Ship Construction, J. F. King. Instn. Naval Architects—Advance Paper no. 1, meeting March 16, 1932, 6 pp.

Stainless Steel and Shot-Welding, E. J. Ragsdale. Aviation (April 1932), vol. 31, no. 4, pp. 177–179. Technique developed by E. G. Budd Manufacturing Co. to prevent deterioration of materials during welding process; shot-weld in 18-8 should show twice shearing resistance of rivet of like diameter and of same material.

Steel Barrels from Flat Sheets in One Hour. Iron Age (April 14, 1932), vol. 129, no. 15, pp. 876–878.

Structural Steel Welding. Cutting Building Costs by Electric Arc Welding, A. M. Candy. Contract Rec. (April 6, 1932), vol. 46, no. 14, pp. 372–376.

Structural Steel Welding. Welding as Applied to Steel Structures, L. H. Miller. Mech. Engr. (March 1932), vol. 50, no. 1, pp. 6–9.

Structural Steel Welding. Temporary Connections for Arc-Welded Structures, Van R. P. Saxe. Gen. Bldg. Contractor (April 1932), vol. 3, no. 4, pp. 11–12.

Tanks. Cutting Down and Re-erecting Gas-Welded Tanks Economically, M. K. Allen. Welding (March 1932), vol. 3, no. 3, pp. 158–60. Economies effected by gas welding and cutting from standpoint of salvage, which was 42.2% net, as compared with less than 10% for riveted tank moved to another field.

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